DIGITAL DISASTERS: THE ECONOMIC COSTS OF SUBMARINE CABLE BREAKS*

Joël Cariolle[1,2]

[1] Fondation pour les Etudes et Recherches sur le Développement International (Ferdi), 63 boulevard François Mitterrand, Clermont-Ferrand, 63000, France.

[2] University Clermont-Auvergne, CNRS, IRD, CERDI, Clermont-Ferrand, 63000, France.
Email: joel.cariolle@ferdi.fr

May 22, 2026.

Abstract

I estimate the economic costs of disruptions to submarine cables, the backbone of cross-border data traffic, using a new dataset covering 146 economies from 2008 to 2020. Exploiting random variation in disruption occurrence and repair duration, I use a dynamic staggered difference-in-differences design to identify direct losses and regional spillovers. A typical disruption opens an immediate gap in GDP per capita that compounds over time: six years after a disruption, GDP per capita drops roughly 9% below that of non-disrupted economies in the same region. This divergence is accompanied by a similar decline in trade, private consumption, FDI, and productivity, and an increase in financial frictions. Shifting the counter-factual to non-disrupted economies outside the affected regions yields a GDP decline of about 5–7% over the same time horizon. In fact, non-disrupted peers in disrupted regions experience growth gains, supported by diversion of trade in digitally intensive services and reallocation of foreign investment and productivity. Evidence from exporter data confirm these patterns. On the import side, the number of foreign exporters supplying disrupted markets falls over three years; on the export side, disrupted markets experience a rise in exporter exit along with a drop in surviving entrants, while non-disrupted regional peers expand their exporter base.

Keywords: Submarine cables, connectivity, internet disruptions, economic growth, digital infrastructure.

JEL Classification: O40 , L96 , F43 , O33 , H54.

*I am grateful to Tanguy Bernard, Simone Bertoli, Pierre Biscaye, Vianney Dequiedt, Martina Ferracane, Andres Figoli, Georges-Vivien Houngbonon, Florian Léon, Nicola Limodio, Jordan Loper, Francesca Marchetta, Peter Neis, Eric Rougier, Tarna Silue, as well as participants of the CERDI-UCA and Bordeaux School of Economics research seminars, for their useful feedback. I am also grateful to Issakha Thiam for his support to Cloudflare data collection and treatment. This work was supported by the Agence Nationale de la Recherche of the French government through the programme 'Investissements d'avenir' (ANR-16-IDEX-0001), through the IDGM+ initiative led by Ferdi (Fondation pour les études et recherches sur le développement international).

1 Introduction

International trade, finance, and production networks rely on reliable cross-border data connectivity. Submarine cables (SMCs), carrying 99% of cross-border data traffic (Telegeography 2023), thus form the first-mile backbone of the global economy. Yet these cables are vulnerable to accidental failures that can disrupt payments, logistics, and digital services across multiple countries, industries and firms for days or weeks. The concern for this new digital risk has recently gained salience among European governments, to such an extent that undersea cable security was elevated to a national priority[1]. Despite the role of submarine cable network as the backbone of world exchanges, and the rising awareness of their vulnerability, the literature still lacks empirical evidence on the economic costs of their failures.

This paper provides causal evidence on the short- and medium-run macroeconomic effects of accidental submarine cable disruptions. Using a new cross-country dataset spanning 2008–2020, I exploit exogenous variation in the timing and duration of disruptions in a dynamic event-study difference-in-differences framework. Because failures can divert activity to nearby economies, I separately identify direct losses for disrupted countries and spillovers to proximate non-disrupted peers. Estimates show that a typical disruption opens an immediate gap in GDP per capita that compounds over time. Six years after a disruption, GDP per capita stands roughly 9 percent below that of non-disrupted economies in the same region, while these regional peers experience contemporaneous growth gains consistent with reallocation. Shifting the counterfactual to non-disrupted economies located in non-disrupted regions, estimates support a decline of about 5–7% in GDP per capita, with the remaining gap accounted for by spillovers on regional peers. I then use evidence on consumption, trade, services, investment, productivity, and banking outcomes to trace the propagation channels and to inform infrastructure policy margins that shape resilience.

In 2024, cable breaks were the leading cause of global internet shutdowns in terms of countries affected, and the second in terms of occurrence after government shutdowns.[2] Yet, the literature still lacks evidence on the causal macroeconomic consequences of SMC failures. Existing assessments of connectivity disruptions are largely accounting exercises and consider other disruption causes, such as government shutdowns. Deloitte (2016) estimates that connectivity disruptions can destroy hundreds of millions of dollars in GDP within days, while The Brookings Institute (West 2016) estimated global GDP losses from government-induced internet shutdowns at \$2.4 billion annually, with some country-level losses reaching nearly \$1 billion. Beyond identification concerns, these studies largely overlook submarine cable failures, arguably the most economically damaging source of connectivity disruption given their role as critical first-mile infrastructure in the world economy's architecture, their capacity to affect multiple countries simultaneously, and the extended durations required for underwater repairs. Second, they implicitly treat disruptions as short-lived events, rather than as shocks that can generate cascading effects through persistent output losses across production and service networks, and reshape regional patterns of economic activity.

Yet, connectivity disruptions can depress economic activity through channels that extend well beyond the digital sector. When international connectivity is impaired, firms face immediate information and financial frictions. Orders cannot be verified, payments cannot be executed, and the data-intensive services embedded in modern trade—finance, logistics, transport, and ICT support—are delayed or disrupted. These frictions propagate through supply chains and trade networks as firms reliant on just-in-time logistics and cross-border coordination incur order, payment and delivery

[1]See, for instance, the European Commission Recommendation 2024/779 of 26 February 2024 on secure and resilient submarine cable infrastructure (link).

[2]https://radar.cloudflare.com/year-in-review/2024

delays. Early evidence shows that each additional day of delay in product delivery reduces bilateral product trade by more than 1 percent on average (Djankov et al. 2010), and can be compared to an ad-valorem tariff of 0.6 to 2.1 percent on imported goods (Hummels and Schaur 2013). These costs are likely amplified today by the increasing digitalization of economies and "servicification" of production and merchandise trade (Baldwin 2016).

These shocks can also generate spillovers to nearby non-disrupted economies. By raising information and transaction costs in affected economies, cable failures can weaken competitiveness and trigger regional reallocation: trade, investment, and bandwidth-intensive activities may be diverted toward proximate economies that offer more reliable connectivity. As a result, the resulting growth gap can reflect both contraction in directly exposed countries and contemporaneous expansion among nearby unexposed peers.

This paper provides the first quasi-experimental estimates of the economic costs of submarine cable failures, complementing prior causal evidence on broadband arrival (Hjort and Poulsen 2019; Simione and Li 2021; D'Andrea and Limodio 2024). Identification leverages the fact that cable failures are primarily triggered by maritime hazards (anchors and fishing activity) and occur within a dense network architecture that makes the timing and location of experienced disruptions plausibly orthogonal to contemporaneous macroeconomic conditions.[3] Thus, disruptions are defined from the perspective of what each country experiences, not from its proximity to the event, since a single cable break can simultaneously impair connectivity among distant countries.

Dynamic effects are estimated using the event-study difference-in-differences framework of de Chaisemartin and d'Haultfoeuille (2024), which accommodates staggered timing and non-binary, non-absorbing treatments. Disruption data is drawn and coded from SMC fault reports published by the *Subtel Forum*, the primary source of information, analysis, and market intelligence for the global submarine cable industry. Cable disruption exposure is measured at the country-year level, using the annual number of cable-failures that trigger connectivity loss in a given country (incidence), and the annual number of cable repair days associated with connectivity disruptions (duration/intensity).

To address endogeneity concerns, I test for potential non-random exposure and use a recentered treatment variable following Borusyak and Hull (2023), exclude incidents linked to natural disasters, sabotage, or government-ordered shutdowns, and conduct sensitivity checks — alternative exposure definitions, sequential exclusions of switchers, regions or income groups. I also use an alternative disruption dataset from the *Cloudflare Radar* platform, covering cable disruption events over 2022–2025, to verify that the treatment captures genuine connectivity disruptions rather than idiosyncrasies of data collection or coding. Across these checks, the identifying assumptions are supported by robust and consistent relationships.

The estimates are consistent with submarine cable failures acting as systemic digital risks with large and persistent macroeconomic costs. An average cable disruption, requiring 10–11 cable repair days, triggers an immediate decline in GDP per capita growth and level that accumulates over time, inducing a 9-percent divergence from non-disrupted regional peers' trajectory six years after the connectivity shock. Shifting the counterfactual to non-disrupted economies located in non-disrupted regions attenuates the decline to about 5–7% in GDP per capita, the gap reflecting positive growth spillovers on regional peers. Mirroring GDP dynamics, TFP and labor productivity fall in disrupted

[3] The International Cable Protection Committee (ICPC) argues that accurate charting of submarine cable routes on nautical charts is critical for maritime safety and cable protection, because most cable faults are accidental and largely caused by fishing activity and vessel anchoring (on the order of 70–80% of faults). The ICPC also notes that removing cables from charts would do little to deter deliberate damage, since actors intent on sabotage can locate cables regardless, while de-charting would materially increase accidental incidents (link).

countries and rise in nearby non-disrupted ones, suggesting that the medium-run costs operate through persistent declines in efficiency and regional reallocation dynamics. Disruptions are also accompanied by a contraction of importing and exporting extensive margins and a tightening of financial conditions, with domestic credit to non-financial private agents contracting and cross-border banking positions weakening over time.

Decomposing GDP clarifies where these aggregate losses materialize. GDP losses coincide with contractions in trade and private consumption. Imports of goods and services fall persistently after disruptions, and exports also decline, though less strongly. Private consumption also shrinks, while government consumption rises counter-cyclically, suggesting a partial substitution between private and public spending when connectivity is impaired. In contrast, gross fixed capital formation exhibits only a modest and statistically insignificant decline. Spillovers further sharpen the mechanism, as unaffected countries in the same region expand bandwidth-intensive service exports—especially financial and insurance services—and attract higher FDI inflows following disruptions in nearby economies. The coincidence of these gains with the FDI and productivity decline in affected countries is consistent with diversion of activity toward more reliable locations within the region, so the estimated growth gap reflects both contraction in exposed economies and contemporaneous expansion among unexposed regional peers. Firm-based evidence from the World Bank Exporter Dynamics Database corroborates this channel from two sides: on the import side, disruptions reduce the total number of foreign exporting firms supplying the disrupted market, contracting the import extensive margin; on the export side, disrupted economies see their exporter base shrinking while non-disrupted peers expand it.

Taken together, submarine cable failures warrant treatment as *digital disasters*. They are sudden, plausibly exogenous shocks that disable critical infrastructure and propagate economy-wide with persistence, with estimated welfare losses in the same magnitude class as those documented for climate-attributable extreme weather events (Newman and Noy 2023) or inter-state wars (Federle et al. 2026). Effects are concentrated in countries with limited rerouting capacity—few international cable relations and/or no Internet exchange points (IXPs)—where the absence of redundancy amplifies the transmission and persistence of connectivity shocks. Combining the estimated declines in GDP per capita with these economies' average income levels yields per-event short- and medium-run economic costs of roughly \$0.3–0.4 and \$1.5–2.8 billion respectively (Section 7.1). These magnitudes sit at the upper end of West (2016)'s government-shutdown immediate cost estimates, despite measuring a fundamentally different shock to cross-border (rather than domestic) connectivity. A relevant alternative analogy could be a multi-day national power shutdown, except that no alternative energy source exists at scale: satellite connectivity remains costly and bandwidth-constrained, leaving affected economies with little fallback for the cross-border data flows that underpin modern trade, finance, and production. Unlike natural disasters or armed conflicts, their primary effects operate through disruptions to market access, production linkages, and cross-border financial flows rather than capital destruction, and they can generate reallocation of activity across countries. This absence of capital destruction further precludes the reconstruction-driven recovery growth that typically follows war or natural disaster, consistent with the persistent rather than reverting medium-run GDP profile estimated here. Results also point to clear mitigation levers, since increasing redundancy by diversifying international routes and expanding Internet exchange points fully dampen economic losses, highlighting the value of targeted investments in digital infrastructure resilience.

The remainder of the paper is organized as follows: Section 2 reviews background, mechanisms, and related literature; Section 3 presents the data and empirical framework; Section 4 reports baseline results; Section 5 provides robustness checks; Section 6 analyzes mechanisms and transmission channels; Section 7 concludes with policy implications.

2 Background

2.1 Exposure to cable disruptions as a critical and plausibly exogenous connectivity shock

As broadband access expands, exposure rises where international capacity hinges on a small number of undersea routes and landing points. European policymakers explicitly treat this layer as critical infrastructure: the EU's NIS2 cybersecurity directive brings digital-infrastructure entities operating submarine cables into scope, while the Critical Entities Resilience (CER) directive sets a cross-EU framework to harden such assets.[4] In 2025, the Commission went further with an EU Action Plan on Cable Security to coordinate protection and resilience measures across borders. This policy arc reflects the reality depicted in this paper: subsea cable networks are now critical and their failure can have cascading effects on the economy (Bueger et al. 2022).

SMC faults are common. The global network spans 1.8 million km of telecom cables; 100–200 damage events are recorded annually, concentrated in shallow water (<100 m) where accidental human interactions dominate, especially fishing (nearly half of documented faults) and anchoring. While suspicions of sabotaged cables make the headlines, those episodes remain marginal compared to accidental damages[5], while the ICPC advocates for charting cables on nautical charts to prevent their occurrence[6]. Put simply, the modal break is neither planned nor targeted, it is the by-product of routine seabed activity, and its timing is effectively random relative to a country's macro conditions (Clare 2021; Telegeography 2025b). However, cable faults do not systematically lead to internet disruptions in connected countries.

Exposure to cable disruptions as a random connectivity shock.

Because international connectivity follows shared trunk routes, where a cable fails is not the same as where users feel it. A clear example is West Africa's MainOne system: in June 2017 a fault 3,000 km off Portugal degraded service for customers in Nigeria and across the West African seaboard until repairs completed, illustrating how the network architecture's complexity makes distant breaks bite locally. In March 2024, a separate multi-cable event off West Africa (linked to an undersea landslide) impaired WACS, ACE, SAT-3, and MainOne, causing degraded or near-total outages in at least 10–13 countries despite the damage occurring offshore.[7]

Additional episodes underscore how single or concurrent faults can degrade national connectivity for days or weeks, even when some redundancy exists. In Vietnam, simultaneous problems on the APG and AAE-1 systems repeatedly delayed full restoration through late 2024, with ISPs reporting capacity constraints tied to branch-level faults near Thailand and Singapore.[8] In Pakistan, faults on

[4] Available here.

[5] Telegeography (2025a) invokes *Hanlon's razor* in a piece explaining the causes of undersea cable breaks: "*Never attribute to malice that which is adequately explained by stupidity.*" Talking about recent incidents in the Baltic Sea, a Washington Post article stressed that faults were not intentional but "*accidents caused by inexperienced crews serving aboard poorly maintained vessels.*" Nevertheless, as robustness check, I adjust the disruption exposure's definition by dropping events associated with suspected or confirmed episodes of sabotage, but also to natural disasters that could directly affect growth through physical and human damages.

[6] See ICPC viewpoint.

[7] See Press release, Press release, Press release, Press release.

[8] See Subtel Forum alert.

SMW-4 and AAE-1 in August 2024 slowed traffic nationwide and affected businesses until repairs were scheduled on one system and completed on the other.[9] In South Africa and the broader region, a shunt fault on EASSy in August 2024 followed earlier multi-cable incidents that year, increasing latency on key Middle East and Europe paths.[10]

Whether and where a submarine-cable fault will map into internet disruptions is hence difficult to predict *ex ante* because a physical break does not translate mechanically into who loses connectivity. Depending on how networks are engineered (redundant links, capacity, and contractual circuits), the same fault may make some online destinations unreachable, or instead prompt traffic to be diverted onto alternative routes with heterogeneous effects across networks and locations.[11] Evidence also indicates that impacts can extend beyond traffic that directly used the failed span. In fact, when traffic is shifted onto backups, congestion on those backups can degrade performance even for users whose traffic would not normally traverse the broken cable (Chan et al. 2011). Finally, as noted by the Regional Internet Registry for Europe, Middle East and Central Asia (RIPE), one cannot directly infer which end-to-end paths actually traversed the damaged cables and that comprehensive public data on "who uses which cable, when" are lacking, so the set of affected economies is largely revealed only *ex post*.[12]

Duration of cable repair as a random process.

Around 99% of cable systems are privately owned and thus not "flagged" to any single state, making repair times primarily an issue of international coordination rather than national policy. Repairing a damaged system indeed follows a well-established sequence, independent from country's policies and context.[13] Operators localize the fault, then a specialized repair ship mobilizes, grapnels and recovers the cable, trims damaged sections, splices in new lengths, tests, and re-buries where required (Telegeography 2025b). Today, maintenance relies on regional contracts and zones (e.g., ACMA for the Atlantic, MECMA for the Mediterranean/Red Sea), with a handful of ships covering vast areas, highlighting capacity limits when multiple faults coincide: among the 77 cable ships, only 22 are designed for cable repair.[14] Industry analyses warn that much of the global repair fleet is aging, and that meeting demand and avoiding longer queues will require US$3 billion for 15 replacement and 5 additional ships to sustain service levels as cable-km rise toward 2040.[15] Therefore, determinants of cable repair duration are geophysical and logistical, not driven by national macroeconomic trends or policies, another reason repair duration is treated as a plausibly exogenous "dose" in the event-study and dose–response estimates.

2.2 Related Literature

Early work on the ICT–growth nexus has highlighted the central role and singularity of telecommunications infrastructures as a catalyst for productivity and development. Research by Röller and Waverman (2001), and later Czernich et al. (2011), provides evidence from OECD countries showing that telecommunications and broadband networks generate large growth effects once they reach sufficient scale. These studies show that such infrastructures are not mere capital inputs but vectors that create network externalities and diffuse general-purpose technologies across the economy. Unlike traditional infrastructure such as transport, their value grows with usage, as each additional connection

[9] See Subtel Forum alert.
[10] See Subtel Forum alert.
[11] See RIPE blog.
[12] See RIPE blog.
[13] Cable repair ships are regular civilian vessels flying a national flag, but they operate under international law and large regional maintenance contracts that cover vast ocean areas.
[14] See this piece from The Verge. See also the maintenance map in Appendix A.3.3.1.
[15] See Telegeography's blog.

enhances coordination, reduces costs, and enables complementary innovations. These studies established the principle that digital infrastructure functions as an enabling technology, with effects that spread across sectors and intensify as coverage expands.

Building on these contributions, more recent work has turned specifically to submarine cables, the backbone of international connectivity, and extended the analysis to developing economies (Hjort and Poulsen 2019). First, recent studies have highlighted their contribution to Internet accessibility, especially in Africa (Hjort and Poulsen 2019; Cariolle 2021; Cariolle et al. 2025). Regarding their socio-economic impacts, several recent studies document trade effects of submarine cable deployments. Cariolle and da Piedade (2023) show that improved digital connectedness significantly promotes export upgrading in developing countries. Imbruno et al. (2025) find that bilateral connectivity through shared cable systems facilitates exporters' access to foreign markets, particularly for high-productivity firms. Haltenhof (2019) reports that bilateral connectivity stimulates services trade flows, with elasticities highest in data-intensive sectors, while Herman and Oliver (2023) documents complementary effects in both goods and services trade.

A final strand of research extends the emphasis from trade to domestic and microeconomic activity. Eichengreen et al. (2023) show that the availability of international bandwidth facilitates cross-border financial transactions, lowering frictions in payments and settlements that are critical for trade and capital flows. Complementarily, D'Andrea and Limodio (2024) find that high-speed internet via cables promoted financial technology adoption, expanded interbank market activity, and increased firm access to credit and sales. These results underscore how cable connectivity affects not only cross-border flows but also the functioning of domestic financial systems, amplifying growth potential. In this regard, Simione and Li (2021) use the staggered arrival of submarine cables in Sub-Saharan Africa as a quasi-experiment and find that resulting higher internet penetration rates significantly boost per-capita GDP growth and productivity, while also shifting employment and output shares toward the services sector. This macro evidence is corroborated at the firm level by Hjort and Poulsen (2019), who provide the first causal evidence on how fast internet arrival in Africa, through gradual SMC laying over the last decades, boosts firm productivity, employment, and export performance.

A distinct strand of recent work characterizes the supply-side economics and network structure of the cable market itself. Caoui and Steck (2025) model the global internet backbone as a dynamic entry game and show that buyer demand for route diversification, which hedges against disruption risk, is a primary determinant of cable entry and long-run market structure. Distortions from operators' inability to internalize the social value of diversity are as large as business-stealing distortions. Jeon and Rysman (2025) characterize cross-border data flows as international trade and show that cable capacity is a binding constraint on country-to-country data exchanges, with elasticities of data trade to capacity highest in low-provision settings. Imbs and Pauwels (2025) build a new dataset on global cable topology, redundancy, and capacity over 2010–2025 and show that network vulnerability is persistent, with fragility concentrated along the MENA–South Asia corridor and correlating with network centrality. None of these papers estimates the macroeconomic costs that countries bear when disruptions occur. The present paper complements this structural strand: while Caoui and Steck (2025) identify the market-entry distortions that cause cable redundancy to be undersupplied—operators fail to internalize the social value of route diversity—this paper quantifies the GDP costs that countries bear when the resulting network architecture proves inadequate. The two approaches are therefore complementary, with the structural literature characterizing why fragility persists and this paper measuring what it costs.

This body of evidence on trade and growth effects of SMC connectivity has a direct implication for disruptions. When submarine cables fail, the same mechanisms that stimulate and organize economic activity in normal times operate in reverse, depressing flows through higher transaction and information costs, unreliable transport and logistics, and impaired cross-border coordination. However, the effects of connectivity shocks may be asymmetric as the economic damage from disruptions likely exceeds the proportional benefits of connectivity access due to heightened digital dependence. Modern economies have slowly adjusted around continuous connectivity, with just-in-time supply chains, real-time financial systems, and cloud-dependent operations creating vulnerabilities that amplify disruption costs beyond simple connectivity gains in reverse.

To my knowledge, there is no causal evidence on the macroeconomic costs of connectivity disruptions, and essentially none that focuses on submarine-cable failures. While the papers above characterize the supply structure and network topology of the cable market, and establish that cable capacity shapes data trade flows during normal operation, none identifies how GDP, trade, and welfare respond when disruptions occur. Existing references are primarily policy-oriented accounting exercises. For instance, West (2016) (Brookings) and Deloitte (2016) estimate GDP losses from shutdowns by applying assumed elasticities, sectoral weights, and *ad hoc* multipliers, rather than exploiting quasi-experimental variation to identify dynamic causal effects.[16] These approaches are informative for back-of-the-envelope magnitudes, but they do not address pre-trends, heterogeneous and persistent impacts, or selection into outages.

2.3 Mechanisms

International connectivity is an enabling intermediate input for domestic production, consumption, trade, and finance (Deloitte 2016; Hjort and Tian 2025). Submarine-cable outages restrain international and domestic connectivity access and therefore act as a supply and demand shock that simultaneously lowers operational efficiency and raises adjustment frictions. Notably, these shocks can generate (i) *direct* losses in the affected country due to higher coordination costs, financial and trade frictions; and (ii) *regional spillovers* as trade flows, contracts, and investment are diverted toward substitute locations.

2.3.1 Direct effects

Operational disruptions, payments frictions, and immediate productivity losses

Connectivity loss immediately impairs firms' ability to operate: internal communication and monitoring, digital workflows, cloud-based tools, and remote coordination are disrupted, reducing effective labor input and measured productivity. In parallel, outages disrupt the settlement layer of the economy. Even when production and sales can continue, firms may be unable to issue invoices, receive electronic payments, reconcile accounts, or execute domestic and cross-border settlements. These

[16] Brookings (West 2016) estimates that short-term internet shutdowns have cost countries billions of dollars in lost GDP, from 300 thousands USD in North Korea to almost a billion dollars in India. The Brookings methodology estimates shutdown costs as a fraction of national GDP, weighted by (i) the share of the year affected (shutdown duration), (ii) the extent of the digital economy, (iii) the affected population (for subnational cases), and (iv) mobile penetration rates (for mobile-only disruptions). To capture indirect effects, the report multiplies direct losses by a 1.54 multiplier suggested by Quelch (2009), reflecting the spillovers of internet activity on the broader economy. While transparent, this method is essentially an accounting exercise and does not identify causal dynamic effects.

Deloitte (2016) estimates the per-day economic costs of disruptions at USD23.6 million on average per 10 million people in high-connectivity countries, against USD6.6 million to USD0.6 million in medium and low-connectivity countries, respectively. The study applies country–level elasticities of broadband penetration with respect to GDP, derived from cross–country regressions, to approximate the loss in output per day of disruption. The calculation distinguishes between direct effects (output losses in digitally intensive sectors) and indirect effects (spillovers on supply chains and productivity). To account for heterogeneity, the model incorporates country–specific weights for internet penetration, sectoral structure, and income level. While more granular than the Brookings framework, it remains sensitive to the assumed elasticities and does not exploit quasi-experimental variation.

disruptions delay cash receipts while wages, rent, and input bills remain due, lengthening firms' cash-conversion cycles precisely when uncertainty rises. In working-capital frameworks, longer payment lags tighten liquidity and lead firms to cut employment and production (Barrot and Nanda 2020). This channel therefore predicts an immediate contraction in activity through operational downtime and cash-flow stress.

Hypothesis 1: Connectivity disruptions delay domestic production and reduce labor productivity.

Supply-chain disorganization and trade frictions

Beyond within-firm disruptions, outages raise the costs of coordinating and executing trade activities. International shipments rely on continuous information exchange across firms, banks, insurers, freight forwarders, ports, and customs authorities. By slowing documentation, compliance, tracking, and release of goods, degraded connectivity acts like a time trade barrier: each additional day of delay reduces bilateral trade (Djankov et al. 2010) and is equivalent to a sizable ad-valorem cost (Hummels and Schaur 2013). Because trade is increasingly "servicified"—bundling finance, insurance, transport intermediation, and digital logistics (Baldwin 2016)—connectivity failures that impair these service inputs translate directly into weaker import and export performance. When inputs are relationship-specific and difficult to substitute quickly, disruptions propagate along production networks as buyers cannot seamlessly switch suppliers (Barrot and Sauvagnat 2016), amplifying the initial shock beyond the directly exposed firms.

Hypothesis 2: Disruptions reduce merchandise and service trade, particularly in bandwidth-intensive services.

Amplification through financial frictions

Connectivity disruptions can amplify real effects through two complementary financial channels. First, banking and credit provision are information- and communication-intensive: improved connectivity can expand credit supply and enhance monitoring and competition in lending (D'Andrea and Limodio 2024; D'Andrea et al. 2025). The reverse implication is that disruptions can temporarily impair screening/monitoring, raise operating costs, and worsen credit terms or availability. Second, firms' short-term liquidity needs rise during disruptions exactly when payment frictions and bank intermediation problems make liquidity scarcer. The interaction amplify production and trade frictions, as constrained firms are less able to bridge temporary disruptions, which can turn transitory shocks into persistent losses of jobs and market shares (Barrot and Nanda 2020; Barrot and Sauvagnat 2016). Over longer horizons, if disruptions raise operating and financing wedges differentially across firms and sectors, they may depress investment and slow aggregate productivity growth through reallocation and pro-competitive channels, consistent with the mechanisms emphasized by Varela (2018).

Hypothesis 3 : Disruptions tighten liquidity access, through weakened domestic and cross-border banking activity.

Redundancy and resilience as moderators

A key determinant of growth losses is the availability of alternative independent routes. In wholesale bandwidth markets, downstream buyers value network diversity because purchasing capacity across multiple independent paths hedges against disruptions. In fact, the value of connectivity depends on the extent to which failure risks are imperfectly correlated across routes (Caoui and Steck 2025). When disruptions occur in low-redundancy settings, substitution possibilities collapse and failures propagate at larger scale.

Hypothesis 4: Direct losses are larger and more persistent in low-redundancy settings.

2.3.2 Regional spillovers

Regional spillovers arise because higher trade, financial, information and production costs in the affected economy shift activity toward close substitutes. In spatial equilibrium and trade-based geography frameworks, changes in trade or interaction costs reallocate production, spending, and factor demands across locations, generating indirect effects beyond treated units (Allen and Arkolakis 2014; Ahlfeldt et al. 2015; Donaldson and Hornbeck 2016). In this context, a connectivity failure can induce trade and investment diversion, as contracts, customer support, outsourcing tasks, logistics intermediation, and other digitally enabled business services are rerouted toward nearby countries that remain reliably connected.

Trade diversion

Unlike many natural disasters, cable outages do not destroy physical capital (except for cable owners and operators). Persistent effects are therefore more naturally interpreted as arising from coordination and liquidity frictions, relationship disruption, and the reallocation of contracts and investment, rather than from a reduced capital stock.

Evidence from the natural-disaster literature is nevertheless informative on the micro-foundations of trade diversion and relationship reallocating following large shocks. Using firm-to-firm trade credit data, London and Gigout (2023) show that major disasters abroad durably disrupt buyer-supplier relationships and generate diversion rather than trade destruction: exporters reduce sales to affected destinations primarily by cutting the number of clients and reallocating sales toward unaffected destinations. On the import side, studying the 2011 Japan earthquake, Freund et al. (2022) document that importers more dependent on the shocked supplier substitute away from Japan toward alternative suppliers after the event. Their results suggest that substitution need not take the form of broad diversification or systematic nearshoring in goods-based value chains. Rather, sourcing is often redirected toward a relatively narrow set of alternative exporters. In this setting, the scope for substitution toward proximate unaffected countries may be stronger for coordination-intensive and digitally enabled services, where time zones, language, institutional proximity, and the ability to rapidly re-route contracts can make regional substitutes particularly salient.

Competitiveness and investment reallocation

Investment responses can reinforce this mechanism. The disaster literature also provides evidence that localized shocks can reallocate mobile capital toward unaffected areas. Friedt and Toner-Rodgers (2022) document large and persistent reductions in FDI in disaster-hit regions within India and sizable positive spillovers into otherwise unaffected regions. They show that a substantial share of the lost investment reflects relocation within the country, and the effects persist for several years. In this setting, if connectivity disruptions impair the whole economy, they can lower expected returns to operating in the affected country by raising operational and financing costs, discouraging FDI and accelerating reallocation toward regional alternatives. Foreign investors may therefore postpone, scale down, or relocate projects toward proximate regional alternatives that can deliver services and coordinate cross-border activity more reliably.

Such shifts can also shape aggregate productivity. If disruptions disproportionately raise operating costs or financing constraints for outward-oriented and more productive firms (Imbruno et al. 2025)—those most reliant on cross-border coordination, payments, and digital logistics—these firms shrink, lose contracts, or delay expansion, and activity reallocates toward less exposed (and potentially less productive) producers. At the same time, weaker entry and competitive pressure can slow selection and reallocation toward the most efficient firms, with adverse implications for TFP growth, consistent with the competition-and-reallocation mechanisms emphasized by Varela (2018). As a result, exposed economies can experience persistent competitiveness losses, while nearby non-disrupted economies can attract investment and exhibit higher productivity growth as activity relocates within the region.

Hypothesis 5 : Unaffected neighboring countries experience positive spillovers— leading to higher service outflows, FDI inflows and productivity growth —consistent with diversion of services trade, contracts, and investment away from the affected economy.

3 Empirical framework

In this paper, I estimate the dynamic treatment effects of Internet disruptions caused by submarine cable failures on economic growth and its components, using a country–year panel of 146 countries covering 2008–2020. I use the event-study estimator of de Chaisemartin and d'Haultfœuille (hereafter CDH), designed to study staggered non-binary and non-absorbing treatment with possible heterogeneous dynamic effects on macro-economic outcomes(de Chaisemartin and d'Haultfoeuille 2024).

3.1 Model

A central challenge in estimating dynamic treatment effects with staggered adoption is that standard two–way fixed effects (TWFE) event–study regressions may be biased when treatment effects are heterogeneous across units or over time (Goodman-Bacon 2021; Sun and Abraham 2021; Callaway and Sant'Anna 2021; de Chaisemartin and d'Haultfoeuille 2024). In such designs, the TWFE coefficient can be written as a weighted average of cohort-specific effects, but the weights may be negative and place undue emphasis on comparisons between already–treated and later–treated units, especially in the presence of dynamics (Goodman-Bacon 2021). Recent work proposes alternative difference-in-differences (DiD) estimators that avoid this negative–weight problem by restricting attention to valid two–by–two comparisons and aggregating them with nonnegative weights (de Chaisemartin and d'Haultfœuille 2020; de Chaisemartin and d'Haultfoeuille 2024; Callaway and Sant'Anna 2021; Sun and Abraham 2021).

In the present setting, exposure to SMC failures is staggered, but treatment is neither binary nor absorbing, countries may experience multiple disruptions of varying intensity within the sample period, and a failure in one year does not mechanically imply continued treatment thereafter. Standard staggered-DiD estimators such as Callaway and Sant'Anna (2021) or Sun and Abraham (2021), which are designed for binary, absorbing treatments, are therefore not well suited. I instead rely on the estimator of de Chaisemartin and d'Haultfoeuille (2024) (hereafter CDH), which is designed for heterogeneity-robust DiD with staggered, non-absorbing and non-binary treatments.

Let y_{it} denote the macroeconomic outcome (e.g. GDP per capita growth or log GDP per capita) for country i in year t, and let D_{it} denote treatment intensity in country i, year t (the number of SMC-induced internet disruptions or SMC repair days). Let F_i be the first year in which D_{it} departs from its initial baseline level D_{i1} (which is zero for almost all countries), and define event time as $k = t - F_i$. I estimate

$$y_{it} = \alpha_i + \lambda_t + \gamma_i t + \delta_{r(i),t} + \delta_{c(i),t} + \sum_{k=-K_0}^{K_1} \beta_k \, \text{Event}_{it}^k + \varepsilon_{it}, \tag{1}$$

where α_i and λ_t are country and year fixed effects, $\gamma_i t$ are country-specific linear trends, and $\delta_{r(i),t}$ and $\delta_{c(i),t}$ are region-by-year and income-group-by-year fixed effects, with $r(i)$ denoting country i's World Bank region and $c(i)$ its income group. The pre- and post-event horizons are set to $K_0 = 5$ and $K_1 = 7$, respectively. For never-treated units, $\text{Event}_{it}^k = 0$ by convention. The event-time–by–intensity regressor is

$$\text{Event}_{it}^k \equiv D_{it}\,\mathbf{1}\{t - F_i = k\}, \qquad k = -K_0, \ldots, K_1,$$

so Event_{it}^k equals the number of disruptions (or repair days) that country i experiences k years after its first departure from zero exposure, and is zero otherwise. The coefficients β_k trace out the effect of a one-unit increase in treatment intensity at event time k.[17] Identification relies on a conditional parallel-trends assumption for outcomes in the absence of changes in D_{it}.

3.2 Identification under regional spillovers

An important concern for the empirical analysis is that submarine-cable disruptions may generate interference: outcomes in one country can be affected not only by its own disruption exposure, but also by disruptions occurring elsewhere in the region through diversion and reallocation of trade, contracts, and investment. Since such interference may lead to a violation of the stable unit treatment value assumption (SUTVA), I therefore distinguish between direct effects in treated countries and spillover effects on untreated countries (Hudgens and Halloran 2008; Özler 2018).

I distinguish three groups: (i) *treated* countries T; (ii) *spillover-only* countries S, untreated but located in a region with at least one disruption; and (iii) *pure controls* C, untreated in non-exposed regions. The baseline event-study with region-by-year fixed effects identifies the *direct effect net of spillovers* ($T-S$); a separate event-study on the non-treated sample identifies *spillover effects* ($S-C$). These satisfy the accounting identity $T-C = (T-S) + (S-C)$, from which I recover an *implied ITT* relative to pure controls. The formal potential-outcomes framework, identification assumptions, and mapping to empirical specifications are detailed in Appendix A.2.

3.3 Data

The empirical analysis uses an annual country panel for 2008–2020 that combines macroeconomic variables from the World Bank's Open Database, Global Productivity Database, the Bank of International Settlements Data Portal, with SMC infrastructure data from Telegeography and an original database on cable-related internet disruption episodes. The data coding protocol applied to build cable disruption data is explained in Appendix A.3.1.

3.3.1 Internet disruptions and SMC failures

Definition

In this paper, the treatment is defined at the country–year level as an episode in which a submarine–cable failure generates a measurable loss of international connectivity for that country.[18] Countries that are topologically connected to the faulted cable but for which traffic is rerouted without noticeable service degradation are coded as *not treated*. Therefore, cable failure attribution follows the

[17] By normalization, $\beta_{-1} = 0$. Because treatment is non-binary, I use the `normalized` option in `did_multiplegt_dyn` Stata command, which rescales each local effect by the size of the underlying treatment change before aggregation. The β_k can therefore be interpreted as the average effect, k years after first exposure, of a one-unit increase in treatment intensity (one additional disruption or one extra repair day), relative to a status-quo path in which the country remained at zero exposure throughout; see de Chaisemartin and d'Haultfoeuille (2024) for details.

[18] The unit of analysis is therefore "country experiences an SMC–induced internet disruption", not "cable segment near the country is physically damaged".

principle of material impact rather than physical proximity. Under this approach, a single submarine cable failure affecting multiple countries is recorded as several country-specific events, with affected nations sometimes located far from the break site. Figure 1 maps a well–known incident on the SEA–ME–WE and FLAG systems in December 2008. Shaded countries are those reported by operators and contemporary sources as experiencing multi–day outages or major slowdowns, and coded as treated in the panel.

Fig. 1 Internet disruption events related to SEA-ME-WE and FLAG systems failure in Dec. 2008
Source: Asia Netcom. Note: Asia Netcom omitted to report disruptions recorded in Malta and Italy.

The disruption database was hand-compiled from *SubTel Forum* —the SMC industry's main technical platform— which systematically documents national-level disruptions caused by cable failures.[19] For each event, I distinguish physical *cable breaks* from technical faults or planned maintenance, termed *cable outages*, and I record *repair duration* based on SubTel Forum updates. Unlike Internet disruptions driven by internal policy factors— such as government-ordered shutdowns —submarine cable failures constitute plausibly exogenous shocks that primarily impair cross-border data flows rather than domestic access alone, making them well suited for identifying the effects of international connectivity losses. [20] In fact, most SMC failures stem from incidents caused by maritime activities (fishing, anchoring) (Carter 2009; Clare et al. 2023), but the dataset also records less frequent causes such as natural hazards (seismic events, landslides, storms, flooding), sabotage, and other technical causes (e.g. power failures).[21] This taxonomy allows me to exclude failures plausibly linked to policy or to external shocks that might affect economic activity independently from connectivity.

To study the growth effects of SMC-related connectivity shocks, I use two key variables: (i) the annual number of Internet disruptions caused by cable failures, a *treatment-incidence* measure; and (ii) the number of SMC repair days, a *treatment-intensity* measure. In robustness analysis I separate SMC-related incidents into (i) *cable breaks* (confirmed physical damage requiring a repair ship), and (ii) *cable outages* (service-affecting faults without confirmed physical damage, such as repeater failures or power-feed issues). I also use alternative disruption data from the *Cloudflare Radar*[22] —which

[19]Data are collected from the Subtel Forum's cable faults and maintenance desk, complemented with Akamai "State of Internet Connectivity" reports and cross-checked with targeted web searches.
[20]Concerns about non-random exposure to these disruptions are addressed through pre-trend analysis and placebo-permutation tests in the spirit of Borusyak and Hull (2023).
[21]Natural hazards represent the second most common cause, accounting for less than 20% of failures (Clare et al. 2023), but often generate multiple deep-sea breaks where repairs are more complex. Clare et al. (2023) emphasize that climate change and sea-level rise will however intensify these risks.
[22]See Cloudflare Radar webpage.

provides since 2022 a systematic and documented reporting of connectivity disruptions across the world— to check the reliability *Subtel Forum*'s data and the consistency of estimated relationships.

Descriptive statistics

Summary statistics of these variables are reported in Table 1, and their time and geographic distributions in Figure 2. They reveal that submarine cable failures are relatively infrequent but highly variable events with sizable repair burdens. At the country-year level (Table 1, Panel A), the average country experiences about 0.10 cable disruptions annually, with cable breaks (0.084) more common than outages (0.018); the high standard deviations (0.39 and 0.35) indicate substantial cross-country heterogeneity. On average, a typical disruption is associated with 11 repair days (Appendix A.1.1.3). Therefore, repair activities impose a substantial time cost, averaging almost one day per country-year (0.92) but reaching 80 days in extreme cases, with a standard deviation of 5.4. In global annual totals (Panel B), the sample averages 19 disruptions and 174 repair days per year over 2008–2020. Excluding 2020 (Panel C) reduces these to 14.4 disruptions and 118 repair days, confirming that 2020 was an unusually intense year.

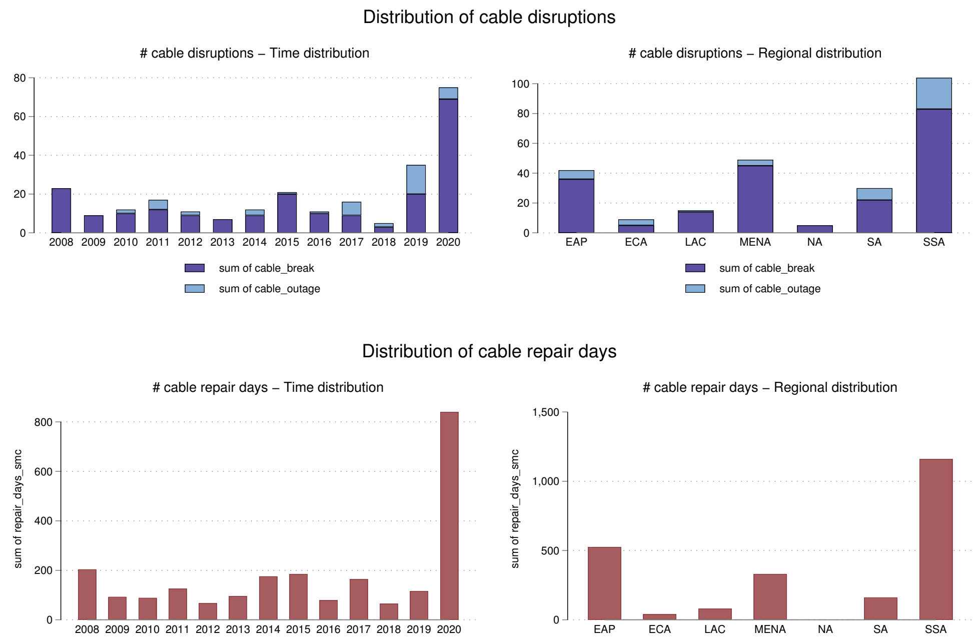

Fig. 2 Internet disruptions and repair days, regional and time distributions, 2008-2020

Aggregating failures by region in Figure 2 (top graphs), Sub-Saharan Africa (SSA) accounts for the largest totals of both Internet disruptions and cable repair days, followed by East Asia & Pacific (EAP), the Middle East & North Africa (MENA), and South Asia (SA). Europe & Central Asia (ECA) and Latin America & the Caribbean (LAC) register much smaller tolls. The contrast between the number of disruptions and the stock of repair days is informative, as a few episodes are long-lived and queue repair capacity. So events' duration, not just incidence, drives exposure. The annual series in Figure 2's bottom graphs show lumpy time patterns and a mild upward shift in disruption counts starting in 2019. Repair-day exposure exhibits much larger variance, with a pronounced spike in 2020. This reinforces the choice to use repair duration as the complementary "dose" variable in the empirical analysis.[23]

While the dataset cannot guarantee complete exhaustiveness of nationwide Internet disruptions caused by submarine cable failures, several features support its reliability. First, *SubTel Forum* is the industry's main reporting venue where operators share infrastructure incidents in real time. Second, the frequency and regional distribution of failures in the dataset align with *Cloudflare*'s automated monitoring system, which, although only available from 2022 onward, provides an independent benchmark. *Cloudflare Radar* reports 26 cable disruptions in 2022, 17 in 2023, and 41 in 2024, with a large share in SSA, echoing the time and spatial distributions of events displayed in Figure 2.[24] This convergence, further explored in robustness analysis, between industry-reported and algorithmically detected sources suggests that the dataset captures the predominant share of economically significant cable disruptions over the study period.

Table 1 Summary statistics of cable failure variables

	Mean	Std. Dev.	Within SD	Min	Max	Obs.
Panel A: Overall sample statistics (177 countries)						
Cable disruptions	0.101	0.392	0.357	0	5	2,478
Cable breaks	0.084	0.352	0.324	0	5	2,478
Cable outages	0.018	0.144	0.135	0	2	2,478
Repair days	0.938	5.437	5.132	0	80	2,468
Panel B: Treated countries, sample statistics (86 countries)						
Cable disruptions	1.328	0.625	0.419	1	5	189
Cable breaks	1.095	0.723	0.502	0	5	189
Cable outages	0.232	0.471	0.345	0	2	189
Repair days	12.938	15.926	10.976	1	80	179
Panel C: Annual sums, 2008–2020						
Cable disruptions	19.08	18.54	–	5	75	13
Cable breaks	15.77	16.89	–	3	69	13
Cable outages	3.38	4.17	–	0	15	13
Repair days	176.92	204.62	–	65	840	13
Panel D: Annual sums, 2008–2019						
Cable disruptions	14.42	8.20	–	5	35	12
Cable breaks	11.33	5.66	–	3	23	12
Cable outages	3.17	4.28	–	0	15	12
Repair days	121.66	48.76	–	65	204	12

3.3.2 GDP growth and other economic outcomes

I study growth and macroeconomic aggregates that plausibly respond to connectivity shocks. For each following aggregate I focus on levels in constant 2015 USD (log) or their growth rates: GDP, household final consumption, government final consumption, fixed gross capital formation, exports and imports of goods and services, and Foreign Direct Investment (FDI).

Because submarine cables are the main digital infrastructure for cross-border data flows, I place particular emphasis on trade, productivity, and financial channels. Therefore, in addition to total trade in goods and services, I study disaggregated trade flows, such as merchandise trade and services trade, but also exchanges of commercial services, ICT services, financial services or transport services.[25] To investigate the mechanisms behind macroeconomic adjustments, I also study the productivity effects

[23] Results are robust to dropping the 2020 spike. See robustness Section 5.
[24] See *Cloudflare* Outage Center.
[25] These services-trade series are available only in current USD; I obtain series in constant dollars using implicit deflators, which are the ratio of the exports (or imports) of goods and services expressed in current USD over exports (imports) in constant USD.

of cable disruptions, using the World Bank Global Productivity Database, and financial frictions, using Credit and Locational Banking Statistics from the Bank of International Settlements. Finally, I use the country-level exporter data from the World Bank's Exporter Dynamic Database to connect empirical evidence from macroeconomic aggregates to observed import and export extensive margins.

3.4 Estimation sample

Estimation's sample summary statistics of cable failures for the estimation sample variables are reported in Appendix Table A.1.1.2. Summary statistics of main macroeconomic outcomes are reported in Appendix Table A.1.1.4.

The estimation sample retained in baseline DID_M estimations consists of 1,898 observations covering 146 countries and 13 years (2008-2020). The estimation sample distribution by region and income group is given in Table 2. It includes 650 observations from high–income countries (HICs) (34%), 234 from low–income countries (LICs) (12%), and 1,014 observations from middle–income economies (MICs) (53%). Regional representation is likewise diverse: Europe and Central Asia (ECA) accounts for the greatest sample share (33%), followed closely by Sub–Saharan Africa (SSA) (27%), Latin America and the Caribbean (LAC) (23%), East Asia and Pacific (EAP) (12%), the Middle-East and North Africa (MENA) (4%) and South Asia (SA) (1%).[26] Among treated countries, SMC disruptions are more recorded among MICs, more located in SSA, while ECA is over-represented in the group of never-treated countries. Additional analysis shows that results are robust to successively removing regions and income-groups from the sample, including removing SSA (Section 5).

Table 2 Estimation sample composition

Panel A. Estimation sample	**Observations**	**Percent**
By income group		
High income (HIC)	650	34.25
Middle income (MIC)	1,014	53.42
Low income (LIC)	234	12.33
By region		
Europe and Central Asia	624	32.88
Sub–Saharan Africa (SSA)	520	27.40
Latin America & Caribbean (LAC)	429	22.60
East Asia and Pacific	221	11.64
Middle East & North Africa (MENA)	78	4.11
South Asia	26	1.37
Total	**1,898**	**100.0**
Panel B. Switchers		
By income group		
High income (HIC)	104	13.56
Middle income (MIC)	481	62.71
Low income (LIC)	182	23.73
By region		
Sub–Saharan Africa (SSA)	403	52.54
Latin America & Caribbean (LAC)	117	13.8
South Asia	13	1.69
East Asia and Pacific	104	13.56
Europe and Central Asia	91	11.86
Middle East & North Africa (MENA)	39	5.08
Total	**767**	**100.0**

[26]Due to identification concerns, North America (USA and Canada) is not represented in the sample since identified cable-related internet disruptions in the region are all located in the US, and caused by sabotage (in 2014 and 2015, in the San Francisco Bay) and natural hazards (in 2008). Results remain however robust to considering these events and region in the estimation sample and are available on request.

Baseline treatment–path diagnostics in Appendix Table A.1.2.1 show that both treatment variables generate a rich variety of paths that allow us to recover six post-treatment effects. In fact, almost 40% of switchers (22 of 58) have a fully-observed window of 6 post-treatment periods in the baseline estimation sample. For the cable-disruption count, roughly 80-90% of groups follow four main paths in which treatment intensity switches on once and then remains stable. For the repair-days measure, treatment paths are more dispersed across groups, reflecting the fact that outage duration varies more flexibly year by year. Nonetheless, a sizeable share of groups still follows a small number of dominant paths, and the detected paths cover all switching groups, so dynamic effects are well identified in the full estimation sample. Repeating the exercise excluding 2020, which features an unusually high number of disruptions at the very end of the sample, yields an even more concentrated distribution of treatment paths (a few simple paths account for a larger share of treated groups).[27]

4 Main Results

This section presents baseline evidence on the growth effect of cable failures. The goal is twofold. First, to establish whether exposure to cable disruptions is followed by movements in GDP per–capita growth and level, and second, to assess whether the magnitude of these effects scales with the duration of disruptions. The analysis begins with baseline estimations assessing the average dynamic effect across exposed countries, before turning to spillover analysis and heterogeneity tests that explore whether digital infrastructure characteristics conditions shocks transmission to the whole economy.

4.1 Baseline estimations

Figure 3 and the detailed estimation tables (Appendix A.1.2.2) report the dynamic effects of cable disruptions on GDP per capita growth and level.[28] Results show flat and insignificant placebo leads, supporting the parallel trends assumption, while the test of joint nullity of coefficients rejects the null at less than 5%. Following an SMC disruption, GDP per-capita growth experiences an instant 1.9 percentage point (pp) drop, which worsens and persists significantly starting year 4: roughly -5.5 pp by $t+3$, -8 pp by $t+5$, and -9 pp by $t+6$. In log-level terms (Figure 3, lower panel), this trajectory corresponds to GDP per capita roughly nine percent below the trajectory of non-disrupted economies in the same region six years after the disruption.

Replacing the cable disruption number with the number of cable repair days confirms previous growth patterns and adds interpretability to the results (Figure 3, bottom panel). One additional cable repair day depresses per capita growth by 0.17 pp at short horizons, reaching over time roughly -0.48 pp (year $t+3$), -0.61 pp (year $t+4$), and stabilizing at -1 pp ($t+5$ and $t+6$). With an average duration of repair of around 10-11 days, this estimate is consistent with estimates using the disruption episode variable. Log-level specifications show a comparable dynamic effect of repair days: an immediate drop of 0.14% on year t, amplifying at year $t+2$, and finally peaking at 0.8% on year $t+6$.

Appendix Figure A.1.2.1 reports significant and consistent estimates from a baseline specification excluding income-group-by-year fixed effects. The parallel specification excluding region-by-year fixed effects is presented in Section 4.2 (Figure 4) as part of the regional spillover analysis.[29] Country-level leave-one-out (LOO) re-estimations (Appendix Figures A.1.3.1 and A.1.3.2) further confirm that

[27]Nevertheless, I retain 2020 in the baseline estimations and use the exclusion as a robustness check.
[28]The concern for thin tail noise at late horizon is lowered by the decent number of switchers (22) and contributing observations (150) at year $t+6$. See Appendix A.1.2.2.
[29]Additional estimations reported in Appendix A.1.8.2 show that the GDP decline is not caused by the recurrence of those connectivity shocks.

point estimates remain negative across all 41 single-switcher exclusions: at $t{+}6$, the LOO distribution spans roughly -8 to -10.5 pp for GDP per capita growth and -6 to -10.5% for log GDP per capita, with no single switcher moving the headline outside the full-sample 95% confidence band.

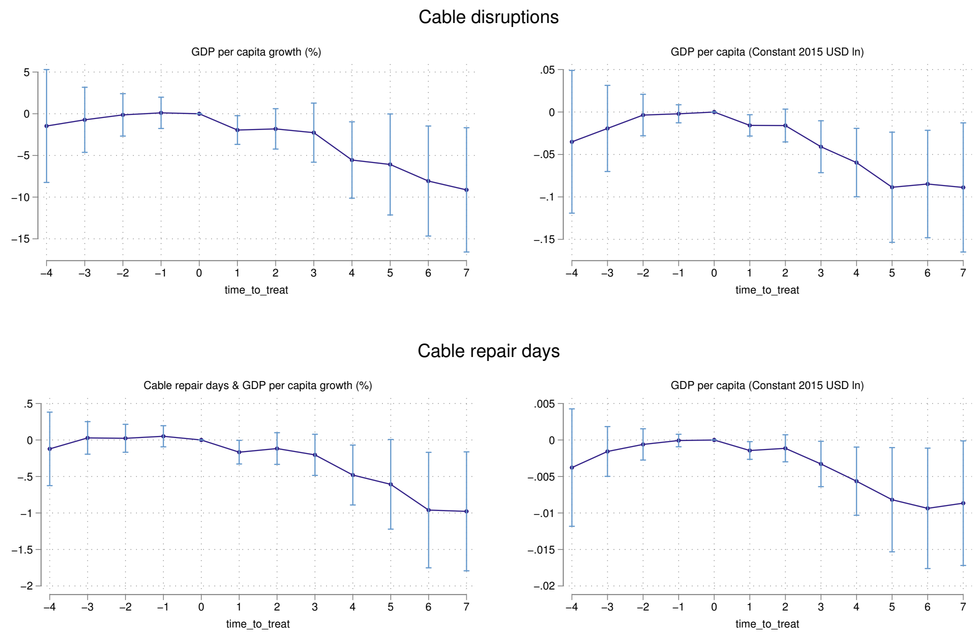

Fig. 3 Cable disruption: GDP per capita growth and level effects.
Notes: Left panel reports event–time coefficients for GDP per capita growth (%); right panel reports event–time coefficients for log GDP per capita (constant 2015 USD). Top panel reports event–time coefficients with the disruption count variable; bottom panel reports event–time coefficients with the repair days count variable. Both panels show 95% confidence bands. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

4.2 Regional spillovers

As discussed in Section 3.2, in the presence of interference the baseline GDP effects should be interpreted as *net* losses, reflecting an economic divergence process rather than an raw loss. In fact, part of the relative decline in exposed economies may reflect contemporaneous gains in proximate, non-disrupted countries.

A first read of the raw loss in exposed economies obtains from re-estimating the baseline event study with a broader counterfactual, by dropping region-by-year fixed effects while retaining country, year, country-trend, and income-group-by-year fixed effects (Figure 4; detailed estimates in Appendix Tables A.1.2.5 and A.1.2.6). The estimation sample now includes, in the control set, non-treated countries in non-disrupted regions, plausibly insulated from any regional reverberations of cable failures. Over the medium-run horizon, log GDP per capita stands roughly 5–7% below this broader counterfactual—about -6.4% at $t{+}5$ and -6.9% at $t{+}6$ for cable disruptions, with comparable magnitudes scaled to the average repair-days episode—against roughly 9% in the baseline specification. The two-to-four percentage-point attenuation relative to the within-region baseline is suggestive of regional spillovers offsetting part of the relative decline in exposed economies. The broader-counterfactual estimate is itself robust to single-switcher exclusions, as country-level leave-one-out re-estimations

(Appendix Figure A.1.3.3) yield point estimates ranging from −4% to −8% at t+6, with all 41 LOO estimates remaining significantly negative.

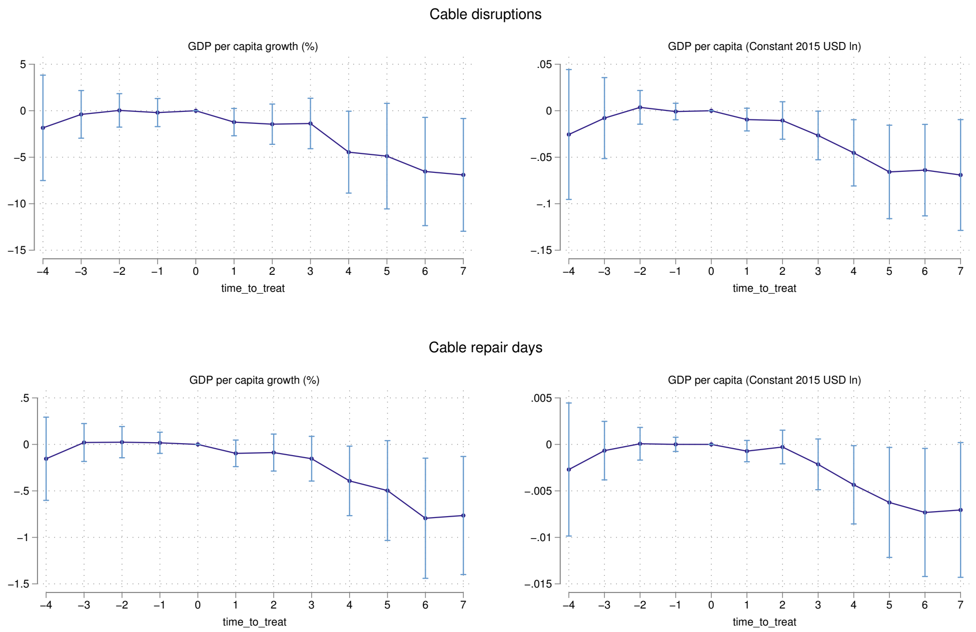

Fig. 4 Total effect of cable disruptions on GDP per capita: broader counterfactual.
Notes: Event-study estimates from the baseline specification re-estimated without region-by-year fixed effects, broadening the counterfactual to non-disrupted countries outside the affected regions. Top row shows effects of cable disruptions on overall GDP growth (%, left), log GDP per capita (center), and log GDP (right). Bottom row shows analogous effects for cable repair days. All panels report event–time coefficients with 95% confidence bands. Specifications include country fixed effects, year fixed effects, linear country trends, and income-by-year fixed effects, with standard errors clustered at the country level.

To test more directly for regional spillovers, I construct two *peer–disruption* variables that sum at the regional level i) the number of disrupted (affected) economies, or ii) the number of cable disruption episodes (one episode can affect multiple countries). Using these two variables, I estimate an event-study specification on the subsample of country-years with no domestic cable failure ($D_{it} = 0$), where treatment varies only through exposure to disruptions occurring elsewhere in the same region.

Because peer exposure is defined at the region×year level, region-by-year fixed effects cannot be included in this design. Identification indeed comes from comparing non-treated countries in exposed region-years to non-treated countries in non-exposed region-years. All specifications hence include at least country and year fixed effects, and a linear country trend. Income-group-by-year fixed effects restrict the comparison to countries within the same income group in each year, which may exclude potentially relevant control countries from other income groups. I therefore report results both with and without income-group-by-year fixed effects.

Figure 5 plots the resulting coefficients for GDP per capita growth. In all four specifications (disrupted economies vs. disruption episodes, with and without income–group-by-year effects), placebo leads are statistically indistinguishable from zero, while post–treatment coefficients turn positive and generally rise over time. With income-group-by-year fixed effects (left-hand side graphs), more disrupted economies are associated with short-run growth gains for unaffected neighbors of around 1–2 pp, which remain positive but are imprecisely estimated at longer horizons. Dropping income-group-by-year fixed effects (right-hand side graphs) yields a starker dynamic, with growth gains increasing gradually and reaching about +2 pp by four to six years after the initial break. Using regional disruption episodes produces a stronger response, with a dynamic effect cumulating to almost +5 pp four to six years after disruptions (See detailed estimates in Appendix A.1.5.1).

In an additional test, the region-level peer exposure to disruptions is replaced with a more targeted measure that counts disruptions occurring among countries in the same *region and income group* as country i. This refinement tests whether diversion and reallocation mechanisms play among both spatially and economically-close countries, while increasing the size of the "pure control" group (non-treated units with zero regional exposure), alleviating concerns that spillover estimates are driven by a small subset of non-switchers. Appendix Figure A.1.5.4 shows that spillover effects remain robust and become more pronounced under this definition, consistent with diversion and reallocation operating more strongly among similar economies.

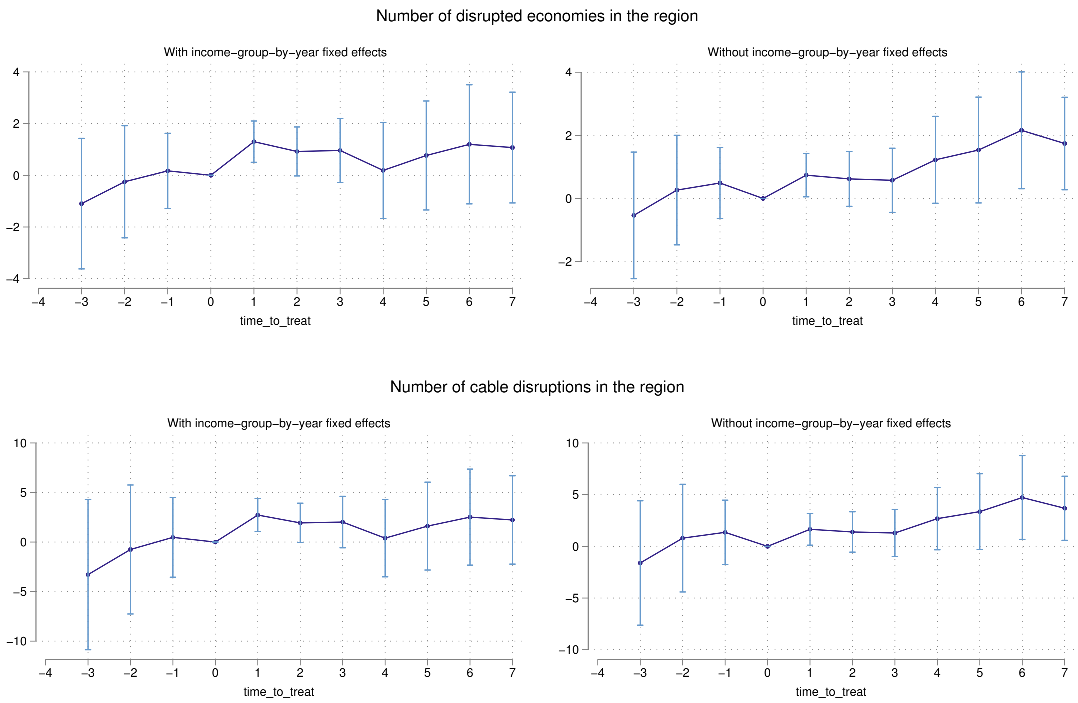

Fig. 5 Regional spillover effects of cable disruptions on unaffected countries' per capita growth rates.
Notes: Figures report event–time coefficients with 95% confidence bands; all specifications include at least country fixed effects, year fixed effects, and linear country trends, with standard errors clustered at the country level. Left-side graphs additionally include *income group* × *year* fixed effects. Year 7 corresponds to a period of six years after the cable failure occurrence. The treatment is either the number of affected economies or the number of disruptions –since one disruption can affect multiple economies– recorded in the region of the non-affected country. Detailed estimates are reported in Appendix A.1.5.1. Additional estimations using region-income-group peer disruption variables, enlarging the subset of never switchers, are provided in Appendix A.1.5.4.

Combining the within-region direct effect identified by the baseline specification $(T{-}S)$ with the spillover estimates from Figure 5 $(S{-}C)$ recovers the total ITT effect through the accounting identity $T{-}C = (T{-}S) + (S{-}C)$, formally developed in Appendix A.2. Appendix Table A.2.3.1 reports the resulting decomposition with joint country-cluster bootstrap confidence intervals. Averaging over horizons $[t{+}3; t{+}6]$, the bootstrap implied $T{-}C$ amounts to -5 to -7 percentage points of GDP per capita growth. This range converges in sign and order of magnitude with the direct estimate of the total effect from Figure 4 (-5 to -7% in log GDP per capita over the medium-run horizon), and confirms that cable disruptions impose persistent losses beyond what within-region comparisons reveal.

4.3 Heterogeneity analysis

Should some affected countries weather SMC failures better than others? Three features of the international infrastructure stack may support an economy's resilience to connectivity shocks. First, having more *SMC landings* can provide spare capacity. Second, *SMC connectedness*, reflected by a broader set of connected partners (distinct foreign landing countries/systems), expands the menu of available routes when one path fails. Third, a greater number of Internet Exchange Points (IXPs) improves networks' efficiency and redundancy by keeping regional and domestic traffic locally rather than hauling them across international links.[30]

To identify heterogeneous effects of SMC failures on growth depending on network redundancy, I split countries at connectivity variables' sample median—2 SMCs, 10 connected partners, 1 IXP—fix the sub-groups at their baseline values, and re-estimate the event studies. Results are reported in Figures 6, 7, and 8. Red hollow markers denote the above-median group effects (high redundancy); blue-filled markers show below-median group effects (low redundancy). For each infrastructure characteristic, the top panels display effects on GDP per capita growth rates, while bottom panels show effects on GDP per capita levels (in logarithms). Left panels use the cable disruption indicator while right panels use annual cable repair days.

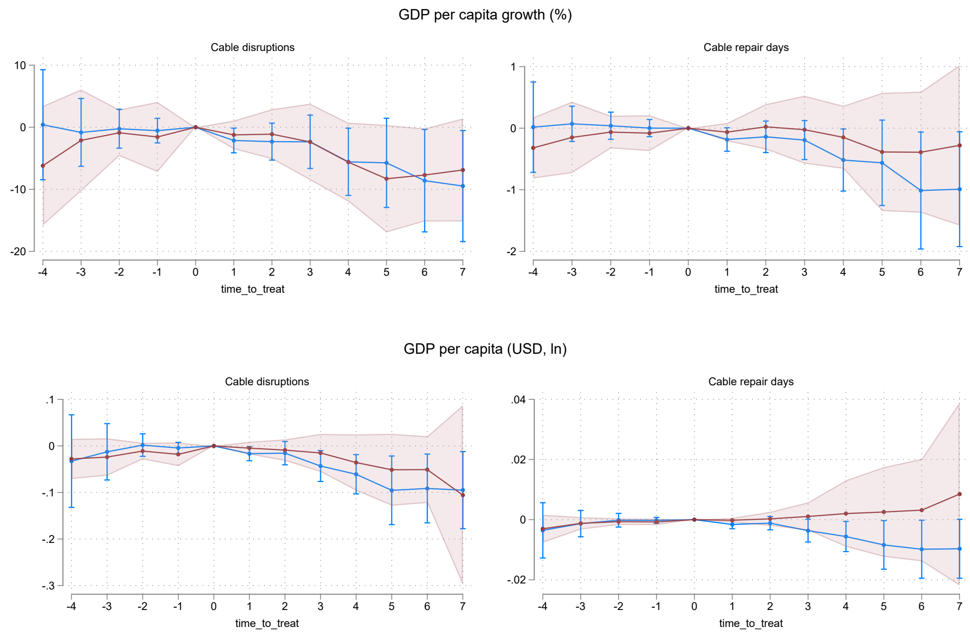

Fig. 6 Exposure factor: SMC density.

Notes: Data on SMC density provided by the author, drawn from Telegeography's SMC map. Red hollow markers = above–median connectivity at baseline; blue filled markers = below–median. Group assignments are fixed at the start of the sample. Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

[30] An IXP is a facility where ISPs, CDNs and other autonomous systems interconnect to swap traffic directly without using international routes; dense IXP presence lowers latency, reduces transit dependence and offers more rerouting options.

The number of connected partners (*connectedness*) emerges as a stronger driver of resilience than the raw count of SMCs (compare Figures 6 and 7). Countries with few connected partners experience a substantial drop in GDP per capita growth following cable disruptions, with effects reaching approximately 10 pp on the medium run for both the disruption indicator and cumulative repair days (Figure 7, top panels). In contrast, where connected partner diversity is high, estimated effects remain close to zero throughout the event window. By contrast, the simple count of landed SMCs contributes less to resilience (Figure 6). While some divergence between high- and low-density countries appears in the growth effects, particularly in the repair days specification, the separation is less pronounced than for SMC connectedness. This suggests that counting cables overstates resilience; what matters for fail-over is route diversity across partners and corridors, which the partner count captures but the raw cable count does not.

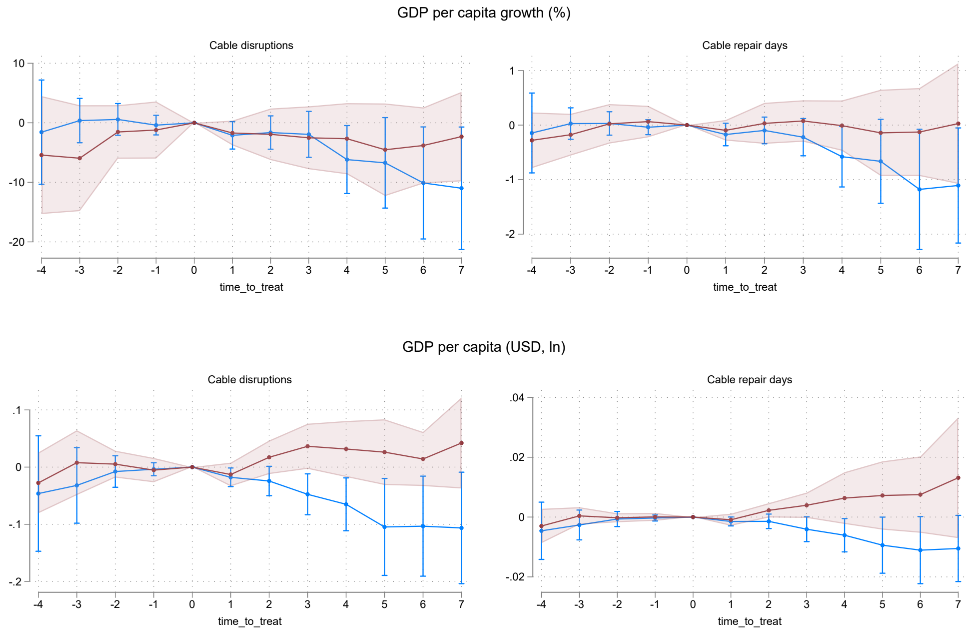

Fig. 7 Exposure factor: SMC connectedness.

Notes: Data on SMC connectedness provided by the author, drawn from Telegeography's SMC map. Red hollow markers = above–median connectivity at baseline; blue filled markers = below–median. Group assignments are fixed at the start of the sample. Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

The level effects (bottom graphs of Figure 7) reinforce these patterns. For connectedness, the divergence is striking. High-connectedness countries experience stable or even slightly positive GDP per capita paths, while low-connectedness countries drive the substantial long-term decline in GDP per capita levels. The cumulative nature of these level effects, visible in both the cable disruption and repair days specifications, stresses how connectivity shocks in poorly connected countries compound into persistent income losses.

The role of IXPs produces a similar heterogeneity (Figure 8). Splitting the sample between countries with and without IXPs at the sample starting date reveals that countries lacking IXPs exhibit pronounced and persistent economic slowdowns in both growth rates and levels. Those with at least one IXP show statistically insignificant movements around zero across both metrics and throughout

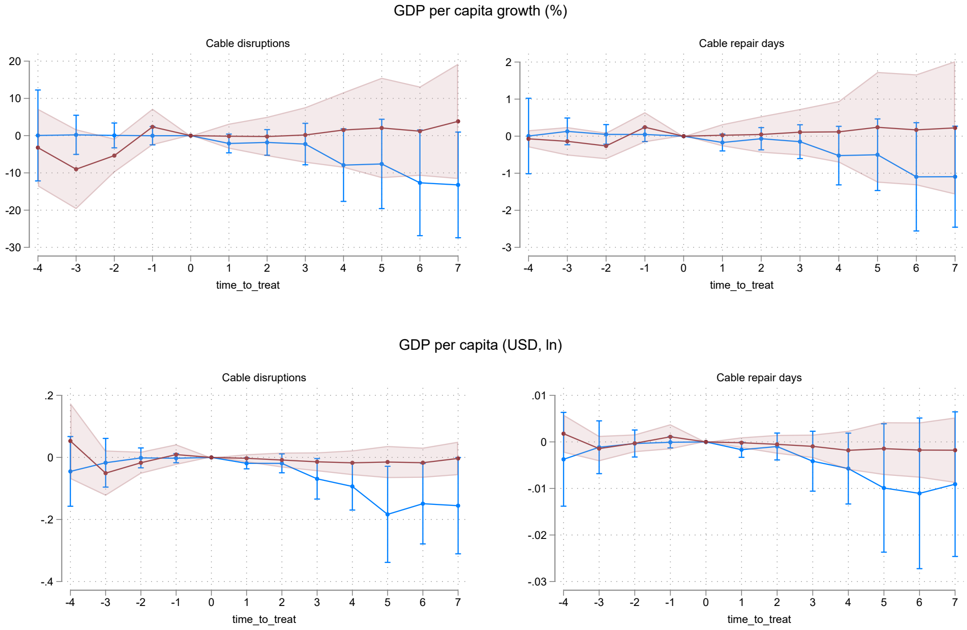

Fig. 8 Exposure factor: IXPs.

Notes: Data on IXPs provided by the author, drawn from Telegeography's IXP map, Packet clearing House, and the Peering DB databases. Red hollow markers = above–median connectivity at baseline; blue filled markers = below–median. Group assignments are fixed at the start of the sample. Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

the event window. Since IXPs localize traffic and reduce dependence on long-haul international routes, this attenuation is consistent with the ability to maintain domestic traffic and to reroute regional and international traffic when international capacity is impaired.

Across all three infrastructure characteristics, the evidence supports that countries entering the period with more connected partners and IXPs do not experience significant growth or level losses from SMC failures. Therefore, contrary to assumptions in prior work (Deloitte 2016), low-connectivity countries suffer disproportionately from connectivity loss, with effects that translate into substantial long-run income gaps.[31]

5 Robustness

The baseline results show large and persistent growth losses after submarine-cable failures. This section probes the robustness of these findings against alternative explanations and potential identification threats. I begin by decomposing the causes of failures, distinguishing exogenous physical breaks from outages, or failures linked to natural hazards or sabotage. I turn to additional sensitivity checks, excluding regions and income groups one by one, as well as removing the outlier year 2020. I also look at how estimates behave after controlling for key potential confounders such as contemporaneous natural disasters, governance quality, maritime connectivity, digital development, SMC connectivity, and macro-economic shocks. I then address the possibility of bias induced by non-random exposure to cable shocks—namely, that countries with for instance poor telecommunications policies might

[31] Additional estimations in Section 5 and Appendix A.1.7.1 show that Internet penetration is not decisive exposure factor compared to connectivity infrastructure.

be more inclined to experience cable-related connectivity losses and worse macro trends—by implementing falsification tests in the spirit of Borusyak and Hull (2023). Finally, I test whether effects hold using an alternative data source on disruption events. Taken together, these checks test whether the observed dynamics are robust to event composition, sample selection, confounding factors, and whether they survive stringent falsification designs.

5.1 Sensitivity Analysis

5.1.1 Composition of failures and exogeneity assumption

A first concern is that the "cable disruption" variable mixes events with different provenance, possibly related to policy factors, or directly affecting macroeconomic outcomes. First, physical breaks, typically due to anchors or trawling, are plausibly exogenous to macro conditions; whereas outages may reflect operator maintenance or soft faults and could be correlated with demand, national policies, or investment cycles. In addition, some disruptions coincide with natural hazards or sabotage, which may themselves be directly correlated to economic and policy factors. In Figure 9, I therefore re-estimate the event studies (i) after excluding all events identified by the Subtel Forum as caused by natural hazards or sabotage, and (ii) separating physical breaks from lighter outages.

The top row of Figure 9 shows that the growth effects remain unchanged when natural hazards and sabotage events are dropped. This indicates that the baseline results are not driven by concurrent macro shocks embedded in the treatment variables. The bottom row separates SMC breaks (left) from SMC outages (right). Break-only estimates display the baseline dynamic, that is, flat pre-trends and a persistent growth deterioration in the same magnitude as baseline estimates. Outage-only estimates are also negative from mid-horizon onward but are smaller in magnitude and non-significant. Taken together, the composition check suggests that baseline estimates are not a result of infrastructure maintenance capacity, natural hazards or acts of sabotage that could challenge the identification assumption.

5.1.2 Excluding regions, income groups and year 2020 from the sample

A natural concern is that the baseline dynamics might be driven by a single geographic block such as SSA, or a specific income group such as MICs, which concentrate the largest number of disruptions. In the same way, the year 2020 is atypical in two dimensions: it records an exceptionally large number of cable failures and repair days, and coincides with the COVID-19 shock, which generated a synchronized collapse in GDP growth across all countries. To probe these potential sources of sample bias, I re–estimate the dynamic specification sequentially excluding each World Bank region, each income group, and by removing 2020 from the estimation sample.

First, Figure 10 reports the resulting event–time coefficients for GDP per–capita growth excluding regions one by one. Pre–trends remain flat in every exclusion, supporting the parallel–trends restriction independent of regional composition. The post–event contraction remain consistent across sub-samples: coefficients move below zero within two–to–three years after first exposure and continue to decline thereafter, cumulating to medium–run losses of roughly 6–10 percentage points by horizons $[t + 5; t + 6]$, well within the baseline confidence intervals. The trajectory obtained after dropping EAP, LAC, MENA, SA, and more importantly SSA, is very close to the baseline.

Dropping Europe and Central Asia (ECA), which represents about one third of the estimation sample and contains many never-treated countries that serve as controls (Figure 2 and Table 2),

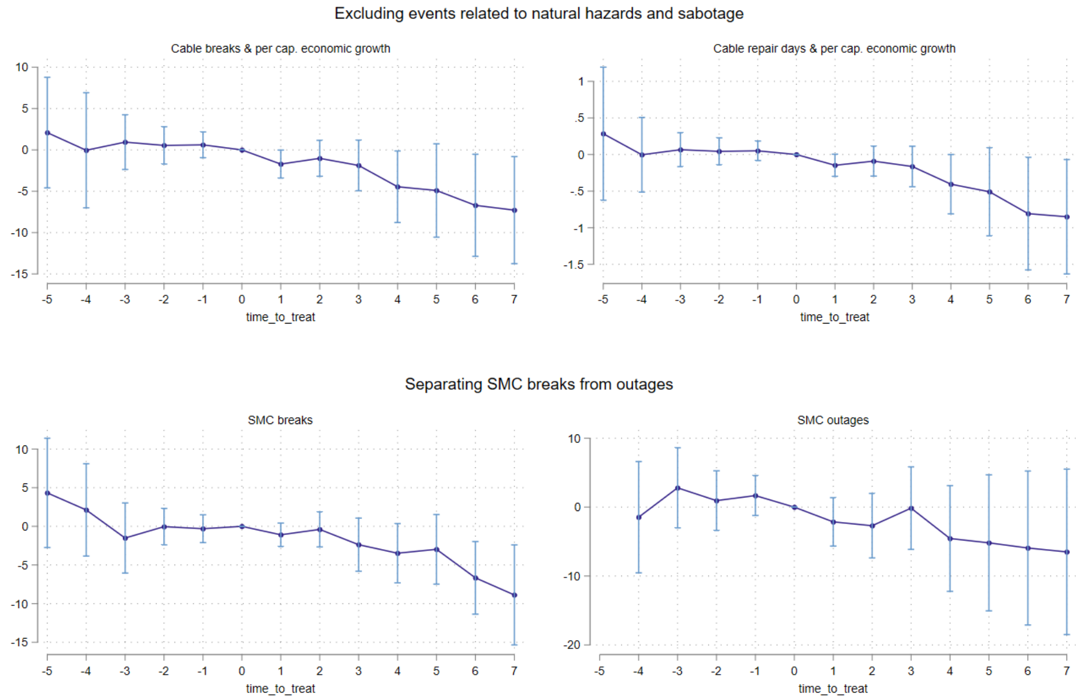

Fig. 9 Composition of failures and exogeneity assumption.

Notes: Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

leaves the shape and magnitude of the dynamic effects essentially unchanged, but slightly widens confidence intervals. This pattern can be explained: although identification relies on within-region timing differences, the precision of the estimates benefits from having a large pool of counterfactuals in ECA.

Second, to ensure that effects are not driven by a specific income group—such as MICs which concentrate most cable failure events, or LICs which may be the most vulnerable to adverse connectivity shocks—I re-estimate the model sequentially excluding each income group from the estimation sample. Results are reported in Figure 11 and show that estimated effects remain robust, suggesting that the significance, magnitude, and dynamic of the growth decline is not related to a specific income group category.[32]

Third, excluding 2020, which is associated with an unusually large number of disruptions exactly when a global, common downturn (COVID-19) hit, leads to identify in Figure 12 a cleaner GDP growth drop in response to cable failures. With year fixed effects, the common COVID downturn is absorbed as a global time shock, so what the estimator picks up in 2020 is only the additional deviation of treated countries relative to already-depressed peers. At the same time, 2020 is the last year of the panel, so countries first treated near 2020 can only contribute to very short-run horizons and never to the medium-run effects. This bunching of many new events at the end of the sample both reduces cross-country counterfactual variation, may introduce noise in immediate shock responses,

[32]The figure reports 10% confidence intervals due to the stringency of this sensitivity check.

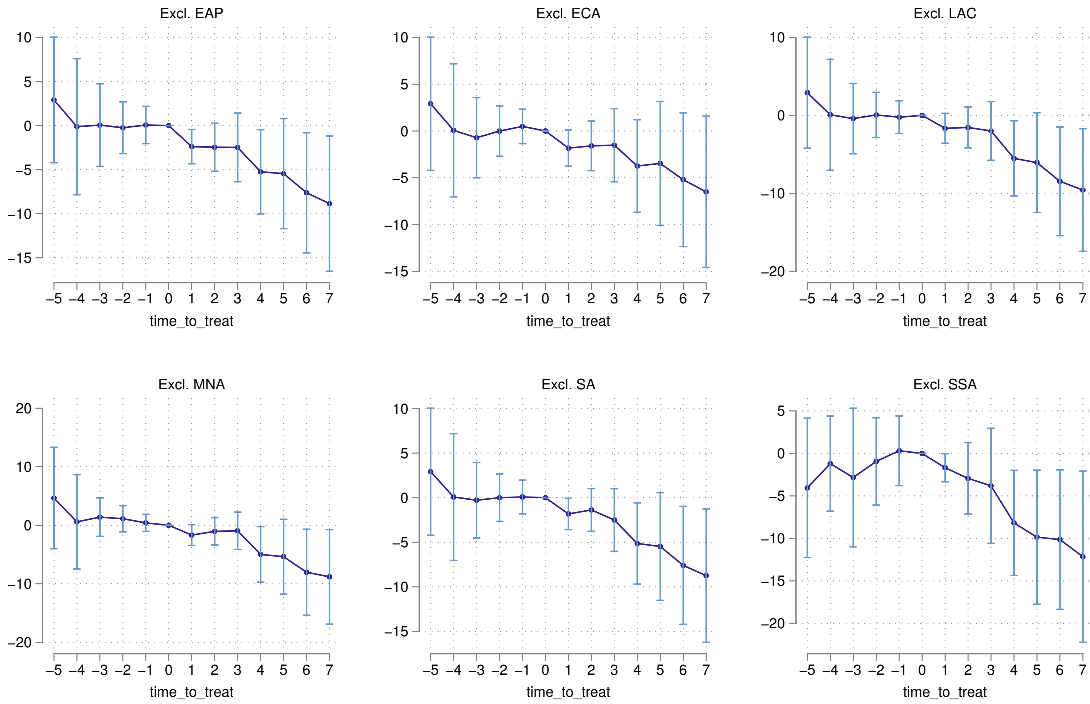

Fig. 10 Cable disruptions and GDP per cap. growth (%) – Estimations sequentially removing regions.

Notes: Event–study coefficients for GDP per–capita growth after sequentially dropping the indicated region. Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

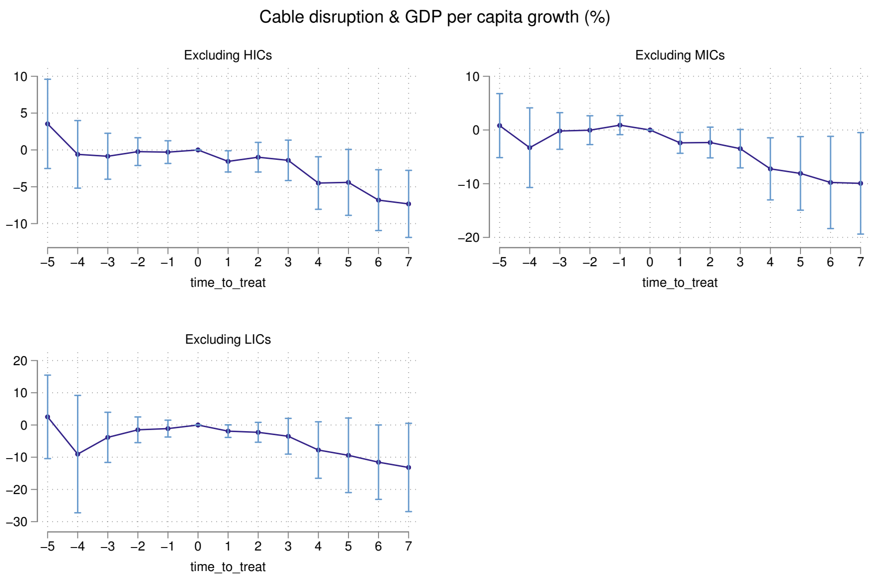

Fig. 11 Estimations sequentially removing income groups.

Notes: Event–study coefficients for GDP per–capita growth after sequentially dropping the indicated income group. Markers show point estimates; bars denote 90% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

while censoring the medium-run response of the "2020 cohort". Dropping 2020 therefore delivers an earlier and cleaner GDP response to SMC failures.[33]

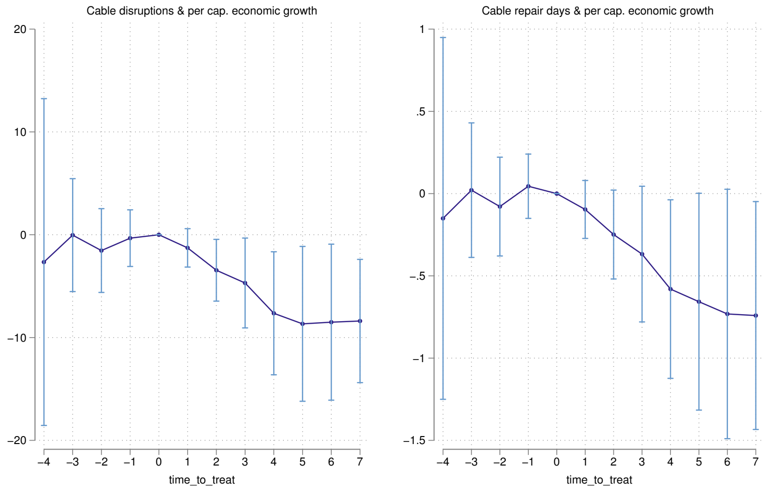

Fig. 12 Cable disruptions and GDP per cap. growth (%), 2008-2019 (excl. 2020).
Notes: Event–study coefficients for GDP per–capita growth after sequentially dropping the indicated region. Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

5.1.3 Controlling for key confounding factors

To assess whether the baseline event-study estimates are driven by time-varying omitted variables correlated with both submarine cable disruptions and economic activity, I re-estimate the dynamic specification after sequentially controlling for a broad set of plausible confounders. Figure 13 reports the resulting event-time coefficients when adding controls for (i) disaster occurrence, (ii) liner shipping connectivity (capturing maritime intensity and trade logistics), (iii) institutional quality, for digital development through (iv) ICT regulatory quality, (v) internet penetration (capturing the degree of digital dependence), (vi) the number of submarine cables and (vii) cable connectedness or path diversity (capturing redundancy and rerouting possibilities), and for macroeconomic shocks through (viii) the real exchange rate index and (ix) net barter terms of trade. Across all specifications, the dynamic pattern is unchanged: pre-treatment coefficients remain close to zero and statistically indistinguishable from zero, while post-disruption coefficients decline over time, confirming persistent growth losses following cable disruptions.

5.2 Non-random exposure to connectivity shocks

My baseline approach interprets the dynamic coefficients in the event–study as causal effects of submarine-cable (SMC) failures under a "conditional parallel trends" assumption: conditional on country and year fixed effects, country-specific linear trends, region and income nonparametric trends, the timing, location, and intensity of SMC-related incidents must be as good as random with respect to future variations in outcomes. However, a key threat is non-random exposure (Borusyak and Hull 2023), since lower-income or lower-growth countries may be more likely to suffer from cable failures

[33] Results are also robust to excluding offshore financial centers. They can be provided on request.

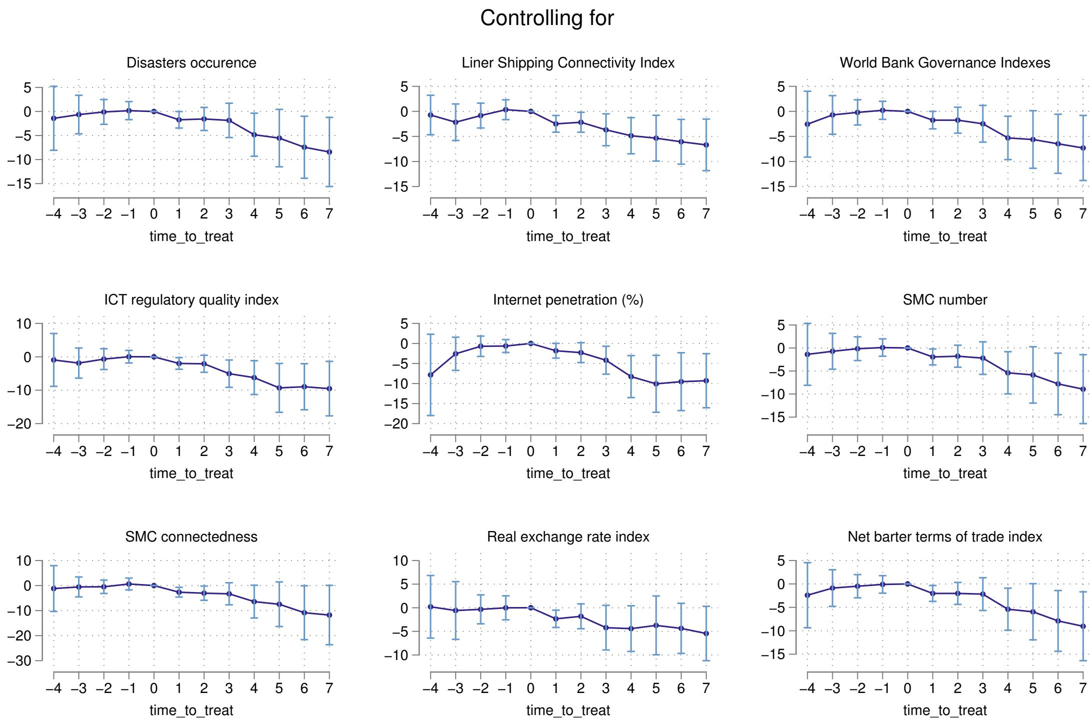

Fig. 13 Cable disruptions and GDP per cap. growth (%), controlling for key confounding factors.
Notes: Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group non-parametric trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence. *Disaster occurrence* controls include the annual number of biological, climatological, geophysical, hydrological, and meteorological disaster events, as reported in the EM-DAT database. To avoid sample attrition, missing value are replaced by 0. Results remain robust to replacing missing values by region×income group×year averages or maximums, and can be provided on request. The *Liner Shipping Connectivity Index*, drawn from the UNCTAD, measures the level of integration of a country or port into the global maritime transport network, by assessing factors such as the number of ships, their capacity, the size of the ships, the number of services and the number of shipping companies. The *ICT Regulatory quality index* is measured by International Telecommunications Union's ICT Regulatory tracker. *World Bank Governance Indexes* include Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption indexes. *SMC connectedness* is the number of distinct cable-connected partners.

(or to record longer repairs) because of poor digital policies, or disruptions in some countries with high digital stakes may be more likely to be detected and reported by the *Subtel Forum*.

In my setting, this identification threat is plausible, as telecom policy, market structure and maturity can shape both exposure and outcomes. For example, weak competition, underinvestment in inland backhaul, shallow redundancy, or slow regulatory coordination can increase both (i) the probability that a cable fault becomes an economy-wide connectivity shock or drags on (long repair windows), and (ii) medium-run growth headwinds. If such latent "vulnerability" evolves over time and is imperfectly captured by the flexible function estimated, the event–time coefficients would be biased downward, because countries drifting downward for structural reasons are also the ones that accumulate more disruption/repair days.

Therefore, a key concern is that a growth-response to internet disruptions is not as-good-as-random, since countries with weak telecoms may both suffer shocks earlier and grow more slowly, potentially biasing event-study coefficients. First, following Borusyak and Hull (2023)'s test of non-random exposure to shocks, I randomly re-assign the timing of disruptions within countries and replicate the dynamic event-study specification 1,000 times over the 2008–2019 period, while enforcing the same estimation sample. Figure 14 presents the results for both GDP per capita growth (top row) and log GDP per capita level (bottom row). In each case, the left panel plots the real event-study coefficients against the 95% placebo band: placebo effects remain centered around zero throughout the event window, while the real coefficients diverge progressively into the lower tail. The right panel shows the permutation null distribution for the average post-treatment effect over t–t+5: the actual average effect (red dashed vertical line) lies clearly in the left tail, with permutation p-values of 0.068 for the growth rate and 0.010 for the log level. Randomly permuted shocks produce no significant effect on either GDP outcome, while the actual estimates lie clearly outside the null distribution, supporting the causal interpretation of the baseline results.

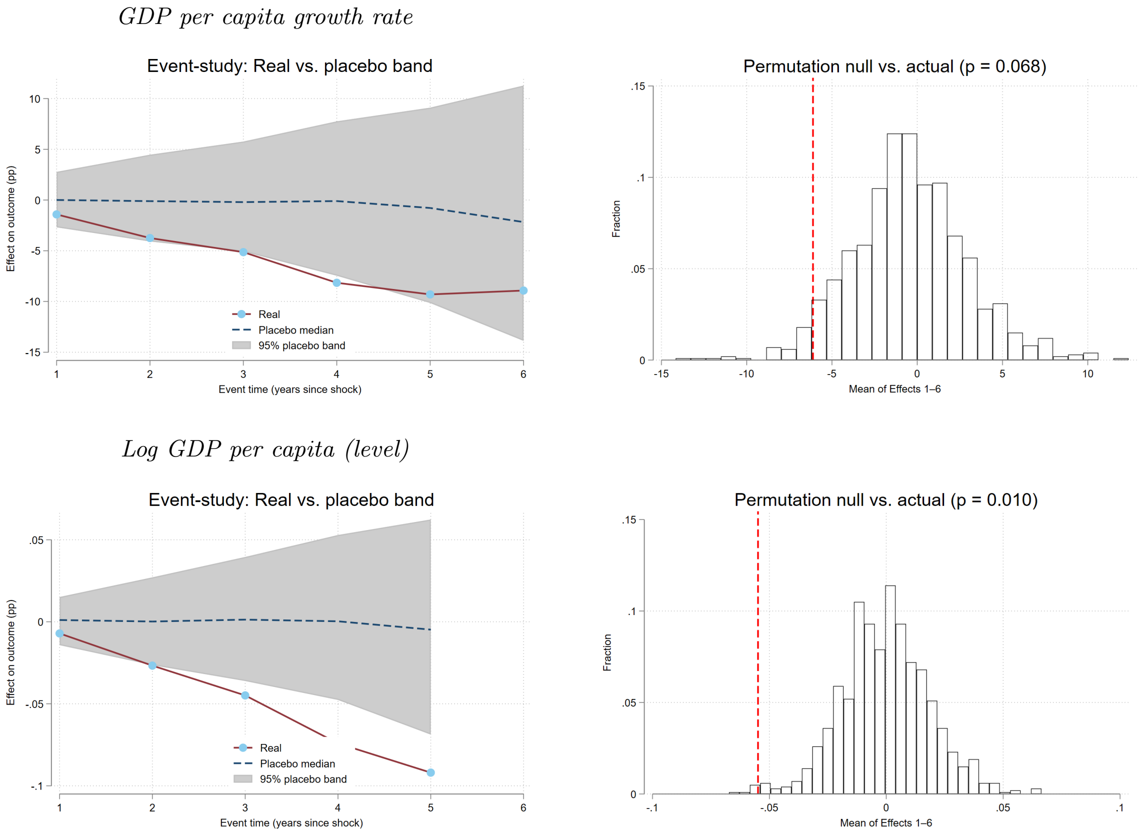

Fig. 14 Permutation test for non-random exposure: real vs. placebo (2008–2019).

Notes: All panels are based on 1,000 random re-assignments of cable disruption timing within countries, over the 2008–2019 sample. *Left panels*: Real event-study coefficients (dark red line with markers) plotted against the 95% placebo band (grey shaded area); the dashed blue line is the placebo median. *Right panels*: Histogram of the permutation null distribution for the post-treatment effect (average event-study coefficient over t–t+5); the red dashed vertical line marks the actual average effect. Top row: GDP per capita growth rate ($p = 0.068$). Bottom row: log GDP per capita level ($p = 0.010$). P-values are computed as the share of permutation statistics below the actual test statistic. Specifications include country fixed effects, year fixed effects, linear country trends, and region-by-year and income-group-by-year fixed effects, with standard errors clustered at the country level.

Second, I recenter the treatment variable following Borusyak and Hull (2023) by subtracting its expected value under uniform within-country timing, retaining only timing variation among countries with identical total disruption burdens. Appendix Figure A.1.8.1 reports the results. In the baseline specification with income-group-by-year fixed effects, the recentered estimates are negative and persistent but imprecisely estimated, reflecting sample attrition under high-dimensional fixed effects. Removing income-group-by-year fixed effects recovers estimates consistent with baseline dynamics in sign and magnitude ($p = 0.06$, joint test), with individually significant medium-run effects. The attenuation in the high-FE specification reflects loss of effective identifying variation under sample compression, not evidence of confounding.

5.3 External validation using Cloudflare nationwide cable-cut events over 2022–2025.

A natural concern in studies of rare infrastructure disruptions is whether the treatment indicator captures genuine connectivity shocks rather than idiosyncrasies of data collection or coding. I therefore use independent outage event annotations from Cloudflare Radar as an external benchmark. Cloudflare records nationwide service degradation episodes—supported by observed traffic/connectivity degradation[34]—and classifies them by cause, including *cable cut* events. Since Cloudflare data are not used to construct the 2008–2020 disruption dataset, this data provides an out-of-period measurement validation.

I first show in Figure 15 and Appendix Table A.1.4.1 that countries historically more exposed to submarine cable disruptions in the Subtel Forum-based data —as measured by the country average incidence over 2008–2019— subsequently exhibit significantly more Cloudflare nationwide *cable cut* events in 2022–2025. This correlation supports the interpretation that the disruption coding captures real nationwide connectivity failures detected by an independent monitoring system.

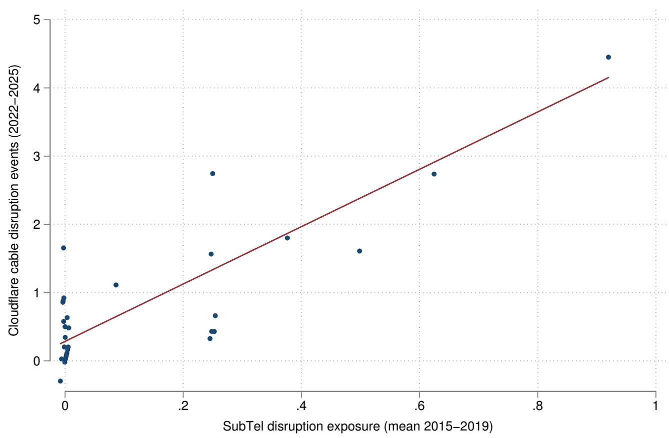

Fig. 15 Correlation between SubTel disruption exposure and Cloudflare nationwide cable-cut events, Binned scatter plot.

Notes: The Cloudflare variable is the cumulated sum of cable disruption events detected by the Cloudflare Radar from 2022 to 2025. The Subtel variable is the average number of cable disruption events reported by *Subtelforum* from 2015 to 2019. Results are robust to using alternative averaging periods. Sample of 109 developed and developing economies.

I then re-estimate the baseline event-study specification using Cloudflare cable-cut events as complementary or alternative treatment. First, I implement a combined treatment that stacks SubTel disruptions (2008–2019 or 2020) with Cloudflare cable cut events (2022–2025), and estimate dynamic effects over 2008-2025[35] using the same specification as in the baseline analysis. Figure 16's top-row graphs report the resulting coefficients. The short-horizon response remains negative: the first post-event coefficient is about -1.28 pp (90% CI $[-2.54, -0.02]$; 52 switchers). Longer-horizon coefficients report the same persistent and monotonically-increasing negative effects as in baseline estimations.

Second, I restrict the Cloudflare replication to countries that are never-switchers according to SubTel data over 2008–2020 and re-run the baseline estimation framework restricting the treatment to Cloudflare-reported events. In this restricted sample, only a short-term effect is identifiable. Estimates show a negative and significant effect, of rather large magnitude (Effect $1 \approx -4.86$ pp; 90% CI

[34] See Cloudflare Radar webpage.

[35] Excluding the COVID period, i.e. 2021 or 2020-2021.

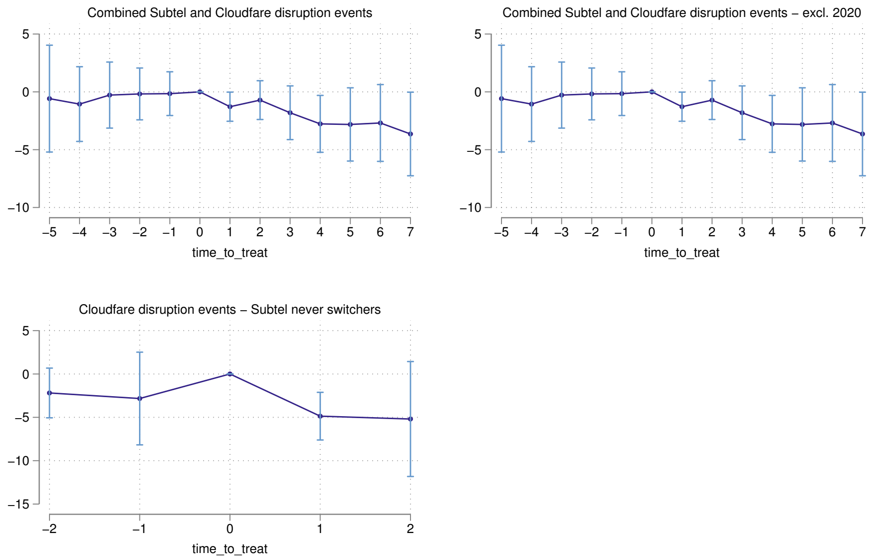

Fig. 16 Cable disruptions and GDP per cap. growth (2008-2025) - Combining Subtel and Cloudflare events.

Notes: Figures report event–time coefficients with 90% confidence bands. All specifications include at least country fixed effects, year, and *region* × *year* fixed effects, a linear country trends, with standard errors clustered at the country level. Top-row graphs include *income group* × *years* fixed effects. The *Cloudflare* variable is the annual sum of cable disruption events detected by the Cloudflare Radar over 2022-2025. Top-row graphs combine (baseline) Subtelforum disruption events (over 2008-2019 or 2020) with Cloudflare disruption events (over 2022-2025). Bottom-row graph displays estimation's result using Cloudflare-only disruptions as treatment variable and a sample restricted to non-switchers according to Subtelforum data. Top-row (left) graph's sample: 102 countries (57 switchers), 1,449 observations (852 switcher-in). Bottom-row graph's sample (Subtel never switchers): 53 countries (9 switchers), 632 observations (96 switcher-in).

[−7.61, −2.12]; joint test p-value ≈ 0.009), while placebo tests are not rejected. Because this restriction leaves few Cloudflare switchers (5 at the first horizon, and fewer at longer horizons), I interpret medium-run coefficients cautiously and view the exercise primarily as supportive evidence that independently coded nationwide cable cuts are followed by an immediate growth shortfall of the same sign as the baseline estimates.

6 Mechanisms

This section explores the mechanisms underlying the persistent growth effects of submarine cable failures.[36] I begin by examining the dynamics of the main components of GDP growth. I then show that the estimated spillovers are echoed by evidence of service trade diversion towards non-affected peers. Then, I highlight the central role of productivity and foreign direct investment: both total factor productivity (TFP) and labor productivity closely track the observed growth dynamics, are accompanied by a decline in FDI inflows, and exhibit similar regional spillover patterns. Finally, I explore the role of financial frictions as a potential shock amplification force. Table 4 at the end of this section scores each of the five hypotheses stated in Section 2 against the evidence gathered here.

6.1 Direct effects on trade, consumption, and investment

The most immediate macroeconomic adjustment to submarine-cable failures occurs through trade. Appendix Figure A.1.8.3 shows that goods-and-services imports and exports fall after a disruption and decline further over time. Imports display the earliest, starkest and most persistent decline: they

[36] Since cable breaks have been identified in Section 5 as the main drivers of growth responses, I use this cable disruption definition as the preferred (because cleaner) treatment variable across this section.

drop by about 5% on impact, with the cumulative point estimate reaching roughly −65% by t+6 (22 switchers). This large magnitude is partly driven by a single switcher (Sudan). Excluding Sudan from the estimation sample reduces the cumulative import decline at t+6 to about −40%. While still substantial, this estimate provides a more conservative benchmark for the long-run effect. Across the leave-one-out coefficient distribution (Appendix Figure A.1.3.4), point estimates at t+6 span from about −45% (Sudan excluded, the single most-influential switcher) to about −77% (Tanzania excluded, which had been moderating the headline), with all 41 LOO estimates remaining negative and significant. Exports follow a similar timing but a less precisely estimated pattern. Goods-and-services exports also contract over the medium run, but in a lesser extent than imports, as confirmed by the external balance on goods and services dynamic. A breakdown of exports and imports response to connectivity disruptions by trade component is given in Appendixes Figure A.1.8.5 and A.1.8.4 respectively. Estimations show that both services and merchandise trade is affected, supporting merchandise "servicification" processes (Baldwin 2016). The sensitivity of cross-border data flows to cable capacity documented by Jeon and Rysman (2025)—with elasticities highest in low-provision settings—implies that reduced available bandwidth translates into fewer data-intensive transactions underpinning both goods and services trade.

Domestically, per-capita household consumption growth turns negative two to three years after the failure and declines monotonically over time, suggesting a lasting hit to household demand rather than a temporary postponement of spending: consumption is about 10% lower at t+3 and around 17% lower at t+6 relative to the pre-event level. On the government side, final consumption appears to play a cushioning or substitution role. Public consumption in real terms starts to rise about two years after the failure. Given the concurrent decline in private consumption, government consumption thus moves in a counter-cyclical fashion, consistent with a counter-cyclical fiscal response. Gross fixed capital formation (GFCF), by contrast, exhibits only a modest and statistically insignificant decrease, suggesting that multi-year project cycles and the mix of public and private investment insulate aggregate capital formation from temporary connectivity failures.

6.2 Service trade diversion

Next, I further test whether growth spillovers are accompanied by service trade diversion dynamics, by examining whether cable breaks raise service and merchandise exports in unaffected neighboring countries. Results are reported in Appendix Figures A.1.5.1 and A.1.5.2. The event–time estimates indicate that spillovers operate almost exclusively through services rather than goods. Merchandise exports of unaffected countries slightly increases when breaks occur but become non-significant afterwards. By contrast, total and commercial service exports respond positively to a neighbor's cable break and stabilize around four years later at roughly 5% above the pre-event level.

Among services, the largest response arises in financial and insurance service exports, which are the most bandwidth-intensive category and display a sustained and amplifying post-event rise from $t+1$ onward, doubling six years after break occurrence. Transport and ICT services also benefit from neighbors' cable failures, with medium-run effects of around +15% and +25%, respectively.

Taken together with the large negative growth effects for directly exposed countries, these patterns are consistent with regional reallocation of digitally intensive activities. When a submarine-cable failure hits one economy, nearby countries that are unaffected appear to capture part of the displaced demand for high-bandwidth services, especially financial and ICT exports. Subsequent sections examine changes in relative competitiveness and financial frictions as the mechanisms behind both the growth collapse in treated countries and the corresponding gains among their neighbors.

6.3 Importer and exporter extensive margins

The aggregate and spillover estimates of previous sections establish trade as the central channel linking connectivity disruptions to the observed growth divergence. Directly exposed countries experience an import collapse that begins at -5% on impact and cumulates to roughly -40% at $t+6$ (excluding Sudan). Unaffected regional neighbours gain approximately $+5\%$ in total service exports, with financial and insurance service exports doubling by $t+6$ and ICT and transport services rising by $+25\%$ and $+15\%$, respectively, calling for a micro-founded account. What firm- and partner-level mechanisms drive such large and sustained trade compression in disrupted economies, and what counterpart expansion materialises in non-disrupted peers?

These questions are addressed by exploiting the World Bank Exporter Dynamics Database (EDD), covering approximately 70 countries over 1997–2014 (2008–2014 in our estimation sample), from two perspectives. The *import-side* draws on the EDD destination panel, which records for each origin–destination–year the count of exporting firms and the number of distinct origin countries. Aggregated to destination–year level, this yields three variables: total foreign exporters, foreign exporters per observed origin country (normalising for partial bilateral coverage), and distinct exporter countries—bounded by the EDD estimation sample maximum of 57.[37] The *export-side* draws on the EDD origin panel, which records entry, exit, incumbents, and survival rates for domestic exporters.[38]

Panel A1 of Table 3 reports import-side results. Along the firm margin, disruptions reduce the average number of foreign exporters per partner by 35.8 on impact (11 per cent of the mean of 309) and by 84.6 by $t+3$ (27 per cent). In levels, the total count falls by 15,642 at $t+3$, 1.5 times the mean of 10,599 and approximately one standard deviation. Along the country margin, a disrupted destination loses 4.4 distinct exporter countries by $t+3$ (15 per cent of the mean of 29.6; $p = 0.022$). These firm- and country-level losses provide a micro-founded account of the aggregate import decline documented in the preceding section, suggesting that the relative trade collapse reflects not merely lower volumes per existing partner but the progressive withdrawal of foreign exporters in disrupted markets and a structural narrowing of the supplier base that is slow to reverse.

Panel A2 shows that the disrupted country's own exporter base contracts in parallel: the domestic exporter exit rate rises by 15 percentage points at $t+1$, and surviving entrants fall by 170 on impact. Both results rest on 4–5 switchers and are directional, but jointly reinforce the picture of eroding trade relationships from both sides of the border.

Panels B1 and B2 document adjustment by non-disrupted regional peers. On the domestic exporter side (Panel B1, breadth measure), incumbent exporters expand by 128–376 across horizons and firm exits decline, with the total exporter pool rising by 366 at $t+2$. On the country-breadth margin, non-disrupted destinations gain 2.0 distinct exporter countries on impact and 1.4 at $t+1$ (6 and 4 per cent of the mean of 31.5; $p < 0.001$), before the effect fades at $t+2$. Panel B2 (frequency measure) replicates these patterns with roughly doubled point estimates — 733 additional domestic exporters at $t+2$, and approximately 4.9 new exporter countries on impact — consistent with each disruption exerting an independent marginal effect on regional reallocation. These firm- and country-level dynamics provide a micro-founded account of the aggregate service trade diversion documented in the preceding section and prefigure the productivity and FDI spillovers discussed below: the reallocation visible in macro aggregates reflects, at the firm level, incumbent exporters in non-disrupted peers capturing demand

[37] Total exporters sums bilateral cells across observed origin countries; the per-partner ratio normalises this sum by the number of observed partners; distinct exporter countries counts origins with at least one observed firm.

[38] For the spillover analysis, treatment is the number of disrupted economies in the region or disruption episodes, estimated on non-disrupted countries.

displaced from connectivity-impaired markets, and at the country level, the rapid diversification of trading partnerships toward newly accessible suppliers.

6.4 Productivity and FDI: direct and spillover effects

Appendix Figure A.1.5.3 traces the dynamic responses of competitiveness-related outcomes for treated countries and their unaffected neighbors following a submarine cable break: FDI inflows, total factor productivity (TFP), and labour productivity. The first three top graphs show that affected countries experience a sharp and persistent deterioration in foreign direct investment inflows per capita, TFP growth, and labor productivity.[39] In contrast, the first three bottom graphs display a mirror pattern for unaffected neighbors: FDI inflows rise, TFP growth strengthens, and labor productivity improves, consistent with diversion of investment and activity toward nearby substitute locations when reliability deteriorates in the affected economy.

The right-most panels help interpret these productivity dynamics through a reallocation/structural transformation channel. In affected countries, the contribution of labor reallocation to labor productivity growth turns negative after the disruption, indicating that productivity-enhancing shifts of labor toward higher-productivity sectors or firms slow down, or even reverse. This is consistent with disruptions hampering the reorganization and scaling of more productive activities (e.g., due to impaired coordination, market access, and cross-border contracting), leading to weaker efficiency-improving reallocation. Conversely, in unaffected neighboring countries, the labor-reallocation contribution becomes positive and increases over time, suggesting that diverted demand and investment are absorbed through expansion of higher-productivity activities, raising aggregate productivity via improved allocation.

Taken together, the productivity responses closely track the growth effects documented in Section 4. In treated countries, the magnitude and timing of the post-disruption decline in TFP growth are similar to the baseline drop in GDP per capita growth, suggesting that the medium-run growth costs of cable failures operate primarily through a deterioration in productive efficiency rather than through immediate changes in factor accumulation. The same logic helps interpret regional spillovers: the strengthening of neighbors' TFP growth parallels the positive GDP per capita growth spillovers, consistent with reallocation of activity within the region toward locations with more reliable connectivity.

6.5 Financial channels

The persistent relative declines in trade and productivity documented above suggest that submarine-cable disruptions generate more than short-run production frictions and may propagate through longer-lasting amplification mechanisms.

Financial frictions are a natural candidate. Digital infrastructure is central to modern financial services, enabling payment systems and information flows within and across borders (D'Andrea and Limodio 2024; D'Andrea et al. 2025). Financial frictions arising from connectivity shutdowns may affect competitive pressure and productivity incentives: evidence from financial liberalization shows that easing asymmetric access to external finance lowers markups and raises productivity through reallocation and pro-competitive channels (Varela 2018). By the same logic, disruptions that tighten

[39] Variables are drawn from the World Bank Global Productivity Database (Dieppe 2021). I report 90% confidence intervals given the relative imprecision of factor productivity and decomposition-based measures, which may not fully capture informal activity in lower-income economies.

Table 3 Import extensive margin and domestic export participation: direct effects and regional spillovers

	t	$t+1$	$t+2$	$t+3$	$p_{\text{eff.}}$	$p_{\text{plac.}}$
Panel A1: Direct effects – Import extensive margin (Treatment: cable disruptions)						
Avg. foreign exporters per partner	-35.8^{**}	-64.6^{**}	-64.8	-84.6	0.066	0.162
Sample mean = 309.2	(15.4)	(23.1)	(39.9)	(57.4)		
N	305	240	157	123		
Sw.	22	16	11	9		
Total foreign exporters	$-1{,}601^{*}$	$-3{,}550^{**}$	$-6{,}156^{**}$	$-15{,}642^{**}$	0.036	0.302
Sample mean = 10,599	(885)	(1,604)	(2,919)	(6,614)		
N	305	240	157	123		
Sw.	22	16	11	9		
Distinct foreign exporter countries	0.54	-0.34	-1.80^{*}	-4.41^{***}	0.022	
Sample mean = 29.6	(0.78)	(0.98)	(0.98)	(1.49)		
N	305	240	157	123		
Sw.	22	16	11	9		
Panel A2: Direct effects – Domestic export participation (Treatment: cable disruptions)						
Domestic exporter exit rate	0.041	0.152^{**}				
Sample mean = 0.383	(0.043)	(0.068)				
N	28	17				
Sw.	5	4				
Surviving entrants	-170^{**}					
Sample mean = 2,398	(76)					
N	18					
Sw.	4					
Panel B1: Spillover effects – Domestic export participation (Treatment: disrupted economies in region)						
Distinct foreign exporter countries	2.04^{***}	1.36^{***}	-0.10		<0.001	
Sample mean = 31.5	(0.19)	(0.18)	(0.40)			
N	112	110	78			
Sw.	75	73	43			
Total domestic exporters	-21	75	366^{*}		0.046	
Sample mean = 17,620	(216)	(201)	(175)			
N	24	22	20			
Sw.	13	11	9			
Incumbent domestic exporters	128^{*}	145^{*}	376^{**}		0.194	
Sample mean = 11,314	(75)	(85)	(177)			
N	23	21	18			
Sw.	13	11	9			
Domestic exiters	-179^{*}	-205^{*}	-502^{*}		0.113	
Sample mean = 5,071	(93)	(107)	(293)			
N	23	21	18			
Sw.	13	11	9			
Panel B2: Spillover effects – Domestic export participation (Treatment: disruption episodes in region)						
Distinct foreign exporter countries	4.89^{***}	3.07^{***}	-0.19		<0.001	
Sample mean = 31.7	(0.46)	(0.41)	(0.80)			
N	112	110	78			
Sw.	75	73	43			
Total domestic exporters	-42	149	733^{*}		0.046	
Sample mean = 17,620	(431)	(403)	(349)			
N	24	22	20			
Sw.	13	11	9			
Incumbent domestic exporters	255^{*}	289^{*}	752^{*}		0.194	
Sample mean = 11,314	(150)	(170)	(355)			
N	23	21	18			
Sw.	13	11	9			
Domestic exiters	-359^{*}	-410^{*}	$-1{,}004^{*}$		0.113	
Sample mean = 5,071	(186)	(214)	(585)			
N	23	21	18			
Sw.	13	11	9			

Notes: World Bank EDD data. Panel A: CDH estimator with country and year FEs, country-specific linear trends, and region×year FEs. Panels B: country and year FEs and country-specific linear trends; region nonparametric trends omitted to preserve cross-regional identifying variation. Panel B treatment: count of disrupted economies (*peer_break*); Panel C: count of disruption episodes (*peer_maxbreak*). SEs clustered by country. *Distinct exporter countries*: origin countries with ≥ 1 observed exporting firm at destination (sample max. 57). N, Sw., and means inline; sample contracts at longer horizons. $p_{\text{eff.}}/p_{\text{plac.}}$: joint-test p-values for effects/placebos; blank = not estimated. Panel A2 results rest on 4–5 switchers (directional). $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

domestic and cross-border finance can weaken competitiveness and depress productivity, helping to explain the effect persistence and the regional spillovers.

6.5.1 Domestic credit

I first examine domestic credit as a potential financial propagation mechanism. Appendix Figure A.1.8.6 reports event-study estimates for credit to non-financial domestic agents using data from the Bank for International Settlements.[40] The estimation sample consists primarily of high-income and emerging economies, which are characterized by relatively deep and stable credit markets. I therefore focus on within-country standardized (z-score) measures of credit stocks, winsorized at the 90th percentile, to capture deviations from each country's own historical norm rather than proportional changes in levels.[41]

Across specifications, I find a persistent and gradually intensifying decline in domestic credit following submarine cable disruptions. The effect is present for total credit to the non-financial sector and is driven primarily by credit to private non-financial actors, with a similar though noisier pattern for bank-originated credit. By contrast, credit to general government follows a smoother trajectory, suggesting that the observed decline is not mechanically driven by public-sector borrowing. There is no evidence of differential pre-trends, and the post-treatment contraction deepens several years after the disruption, consistent with cumulative tightening in domestic intermediation capacity rather than a short-lived adjustment.

In Appendix Figure A.1.8.7, I address possible concerns related to the limited number of treated countries and their relatively large economic size. Switcher countries in the estimation sample are on average larger and more financially developed than non-switchers (Appendix Figure A.3.2.1), raising the possibility that aggregate results could be driven by a single influential economy. I therefore re-estimate the event-study specifications while sequentially excluding each treated country. The similarity of the estimated dynamics across all leave-one-out exercises indicates that the results are not driven by any single large economy.

Taken together, these findings suggest that even in relatively large and financially developed economies, disruptions to digital infrastructure lead to persistent and abnormal tightening of domestic credit conditions. This pattern is consistent with the long-run declines in private consumption and competitiveness documented previously, and supports an interpretation based on sustained financial frictions rather than transitory adjustment.

6.5.2 Cross-border banking

I also study whether submarine cable disruptions are associated with changes in cross-border financial intermediation using the BIS Locational Banking Statistics (LBS). Specifically, I focus on non-bank loan and deposit positions from the BIS Locational Banking Statistics, which capture cross-border exposures of banks located abroad vis-à-vis the non-bank domestic sector. Given the substantial heterogeneity in country size and financial openness in the estimation sample, I scale LBS positions by population size, and examine both growth rates and log levels per capita.

Appendix Figure A.1.8.8 reports event-study estimates for non-bank loans and deposits per capita. I find evidence of a gradual post-treatment decline, emerging several years after cable disruptions.

[40] https://data.bis.org/

[41] I use z-score instead of logarithmic transformation because of the substantially higher stocks of credits in the six switchers than in non switchers (see Appendix A.3.2.1). Distributions of the standardized and non-standardized credit variable are reported in Appendix A.3.2.2. Moreover, given the smaller sample size, I used cable disruptions instead of cable breaks as treatment variable to maximize the number of switchers (using cable breaks leads to having only 3 switchers).

While the estimates are imprecise and confidence intervals widen at longer horizons, the dynamic is consistent across growth-rate and log-level specifications. I interpret these results as suggestive evidence of a weakening in cross-border banking relationships following cable breaks. Rather than an abrupt adjustment, the dynamics point to a gradual retrenchment from external financial intermediation, consistent with increased operational frictions, reduced competitiveness, and heightened risk perceptions documented in earlier sections. In this sense, the LBS evidence complements the stronger findings on domestic credit tightening by indicating that financial retrenchment operates not only through internal intermediation but also through external banking linkages.

Table 4 Assessment of mechanism hypotheses.

H3 (financial frictions) is identified on the BIS subsample of high-income and emerging economies; findings should not be generalized to the full 146-country panel.

	Mechanism	Verdict	Main evidence
H1	Productivity losses	Confirmed	TFP and labor productivity fall persistently in treated countries; labor-reallocation contribution turns negative after disruption; mirror pattern holds for unaffected neighbors (Appendix Figure A.1.5.3)
H2	Trade frictions	Confirmed	Imports fall on impact and contract further at medium horizons; both goods and services affected; import extensive margin contracts through loss of foreign exporting firms in disrupted markets (Sections 6.1, 6.3; Appendix Figure A.1.8.3; Table 3)
H3	Financial frictions	Partially confirmed	Domestic credit to non-financial private agents tightens persistently; cross-border banking positions weaken gradually with wider uncertainty (Section 6.5; Appendix Figures A.1.8.6, A.1.8.8)
H4	Redundancy as moderator	Confirmed	Countries with below-median connectedness and no IXPs bear almost all growth losses; high-redundancy countries show near-zero effects throughout the event window (Figures 7, 8)
H5	Regional spillovers	Confirmed	Unaffected regional neighbors gain in service exports, FDI, TFP, and domestic exporter breadth, consistent with diversion of digitally intensive activities toward more reliable locations (Sections 4.2, 6.2, 6.3; Appendix Figures A.1.5.1, A.1.5.3)

7 Back-of-the-envelope estimations and policy discussion

7.1 Back-of-the-envelope estimations

To put the estimated magnitudes in policy-relevant terms, I express the medium-run loss in relative-to-GDP, per-capita, and aggregate dollar terms. The broader-counterfactual ($T-C$) estimate of Section 4.2 shows a relative decline in GDP per capita of about 1% in the first year and 5–7% five to six years after the disruption (Figure 4 and the bootstrap implied ITT in Appendix Table A.2.3.1). Effects are concentrated among low-connectivity countries—those with few international cable relations and/or without Internet exchange points (IXPs)—which at the time of their first disruption had average GDP per capita of around 4,800–5,700 constant US dollars. Applying the baseline $T-C$ percentage losses to this subsample's average income level implies an immediate decline of approximately 45–55 US dollars per person in the first year, and a cumulated medium-run decline of roughly 240–400 US dollars per person five to six years after the event. With a median population of about 6–7 million inhabitants in this group, these figures translate into an aggregate output loss on the order of 0.3–0.4 billion US dollars in the first year and around 1.5–2.8 billion US dollars per disruption event after five to six years.[42]

These magnitudes sit within the upper range of West (2016)'s major-country shutdown estimates ($10–$23 million per shutdown-day for Brazil, Pakistan, India, and Saudi Arabia), but the underlying

[42]The baseline $T-C$ estimates are applied to the low-connectivity subsample mean rather than to subsample-specific $T-C$ estimates, since the latter become substantially less precise once region-by-year fixed effects are dropped from the heterogeneous-effects regressions.

shocks differ in kind: Brookings tracks government-ordered shutdowns of *domestic* services—mobile networks, messaging apps, social media—which interrupt local digital activity without typically impairing cross-border data flows, international payments, or trade-supporting connectivity. Submarine cable failures, by contrast, sever the first-mile *international* infrastructure on which cross-border trade, payments, and FDI directly depend, propagating through the trade-margin, services-diversion, and financial-retrenchment channels documented in Section 6. The gap with Deloitte (2016)'s per-event figure for low-connectivity countries (around \$0.4 million per day for a country of 6–7 million inhabitants) reflects a further conceptual reversal: the Deloitte framework scales the per-day impact with the size of the digital economy—largely tied to internet penetration—*implying that low-connectivity countries suffer less*; the event-study evidence here points in the opposite direction, with the largest medium-run divergences concentrated precisely in countries with limited cable redundancy and IXP infrastructure, while internet penetration itself does not emerge as a critical driver of the heterogeneous effects (Section 4 and Appendix Figure A.1.7.1). The medium-run aggregate of \$1.5–\$2.8 billion per event further captures the persistent multi-year macroeconomic adjustment that the per-day accounting frameworks, by construction, are not designed to measure.

7.2 Policy discussion

Event–study estimates presented in this paper imply that submarine cable failures are not merely short-lived infrastructure glitches, but a new and major source of macroeconomic vulnerability and growth divergence. The dollar magnitudes recovered in Section 7.1 are disaster-scale: the per-event medium-run cost of \$1.5–2.8 billion sits within the magnitude class of climate-attributable extreme weather events, which Newman and Noy (2023) estimates at around \$4 billion per event globally in direct economic damages and approximately 1% of annual GDP for low-income economies. SMC failures should therefore be viewed as *digital disasters* that induce persistent economic divergence, not as minor, self-correcting shocks. The fact that estimated effects are concentrated among low-connectivity countries—with few cable relations and limited IXP infrastructure—further indicates that resilience margins, rather than exposure alone, drive the cross-country distribution of these losses.

Baseline results survive treatment recentering following Borusyak and Hull (2023) and external validation against independent Cloudflare disruption data. The persistence and magnitude of these losses point to a set of reinforcing mechanisms that extend well beyond the immediate interruption of connectivity. First, cable disruptions generate a sustained loss in competitiveness, reflected in persistent declines in productivity and foreign investment inflows. These supply-side effects weaken firms' ability to compete in international markets and are accompanied by trade and FDI diversion toward unaffected neighboring countries. Second, shocks are amplified by financial channels. I document a persistent and abnormal tightening of domestic credit to non-financial actors—even in relatively large and financially developed economies—as well as a gradual weakening of cross-border banking relationships.

Taken together, these results support a policy agenda centered on reducing countries' exposure to SMC failures and accelerating recovery when they occur. First, building *redundancy* in the international network—through more diverse landing sites, partner routes and avoidance of shared choke points—can reduce the probability that a single break isolates a country. Second, densifying *IXPs* and domestic peering helps localize traffic and facilitates rapid fail-over to alternative paths, thereby protecting domestic activity when international links are partially disrupted. Third, shortening *repair queues*—via adequate maintenance agreements, access to repair vessels and fleet renewal—directly lowers the outage duration that enters the repair-days estimates, and thus the depth of the output losses. Finally, running simulation-based stress tests can help governments and regulators treat cable infrastructure as critical, cross-border infrastructure on par with energy or transport networks. In light of the quantified losses above, investments in redundancy, peering and repair capacity are likely to yield large macroeconomic returns, especially for low-connectivity economies.

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Appendix

A.1 Sample statistics and additional estimations

A.1.1 Sample statistics

Table A.1.1.1 Estimation sample countries by World Bank region

East Asia and Pacific					
AUS	FJI	IDN	JPN	KHM	KIR
MMR	MNG	NZL	PLW	PNG	SLB
THA	TON	TUV	VUT	WSM	
Europe and Central Asia					
ALB	AND	ARM	AUT	AZE	BEL
BGR	BLR	CHE	CYP	CZE	DEU
DNK	ESP	EST	FIN	FRA	GBR
GEO	GRC	GRL	HRV	HUN	IRL
ISL	ITA	KAZ	KGZ	LTU	LUX
LVA	MCO	MDA	MKD	NLD	NOR
POL	PRT	RUS	SMR	SVK	SVN
SWE	TJK	TKM	TUR	UKR	UZB
Latin America and Caribbean					
ABW	ARG	ATG	BHS	BLZ	BRA
BRB	CHL	COL	CRI	CUB	CYM
DMA	ECU	GRD	GTM	GUY	HND
JAM	KNA	LCA	MEX	NIC	PAN
PER	PRI	PRY	SLV	SUR	TTO
URY	VCT				
Middle East and North Africa					
DZA	IRQ	JOR	LBY	MAR	TUN
South Asia					
BTN	MDV				
Sub-Saharan Africa					
AGO	BDI	BFA	BWA	CAF	CIV
CMR	COG	COM	CPV	GAB	GHA
GIN	GMB	GNB	GNQ	KEN	LSO
MDG	MLI	MOZ	MRT	MUS	MWI
NAM	RWA	SDN	SEN	SLE	SOM
STP	SWZ	SYC	TCD	TZA	UGA
ZAF	ZWE				

Notes: Regions follow World Bank's region classification. Sample corresponds to estimates reported in Figure 3.

Table A.1.1.2 Summary statistics of cable failure variables, estimation sample.

	Mean	Std. Dev.	Within SD	Min	Max	Obs.
Panel A: Overall panel statistics (country–year)						
Cable disruptions	0.066	0.324	0.304	0	5	1,898
Cable breaks	0.053	0.283	0.268	0	5	1,898
Cable outages	0.015	0.133	0.126	0	2	1,898
Repair days	0.647	4.815	4.606	0	80	1,893
Panel size: Countries (n) = 146; Avg. years per country ($\bar{T}$) $\approx$ 13.0.						
Panel B: Annual sums, 2008–2020						
Cable disruptions	10.50	15.39	–	0	56	12
Cable breaks	8.25	14.15	–	1	52	12
Cable outages	2.33	3.09	–	0	11	12
Repair days	102.08	166.48	–	0	617	12
Panel C: Annual sums, 2008–2019						
Cable disruptions	6.36	5.90	–	0	22	11
Cable breaks	4.27	3.38	–	1	11	11
Cable outages	2.18	3.19	–	0	11	11
Repair days	55.27	39.55	–	0	122	11

Table A.1.1.3 Repair days by incidence of cable disruptions

Cable disruptions	**Mean**	**Median**	**Std. Dev.**	**Freq.**
		All countries		
1	10.60	4.5	14.49	124
2	17.22	16	17.30	36
3	28.30	26.5	18.00	10
5	50	0	501	
Total	13.26	7	16.19	171
		Estimation sample		
1	11.22	2	17.26	63
2	17.5	16	16.10	20
3	38	44	13.08	3
5	50	0	1	
Total	14.03	5	17.88	87

Table A.1.1.4 Summary statistics of macroeconomic variables, estimation sample.

	Mean	Std. Dev.	Within SD	Min	Max	Obs.
GDP per capita growth (%)	1.181	5.6686	5.379	-49.13	91.78	1,869
GDP per capita (USD, const 2015)	15,135	22,956	2,059	271	181,497	1,636
GDP (USD, const 2015)	2.38e11	6.22e11	3.91e10	3.06e7	4.58e12	1,863
Private consumption (USD pc)	7,494	8,995	607.7	208	44,823	1,349
Government consumption (USD pc)	2,835	4,158	219.6	20.0	21,775	1,350
Gross fixed capital formation (USD pc)	3,245	4,592	1,197.5	22.6	39,166	1,327
Exports of goods and services (USD pc)	8,172	21,353	2,937.5	17.6	214,858	1,353
Imports of goods and services (USD pc)	7,642	17,741	2,733.4	42.0	179,347	1,353
Panel size: Countries (n) = 146; Avg. years per country ($\bar{T}$) $\approx$ 12.8.						

A.1.2 Baseline estimations

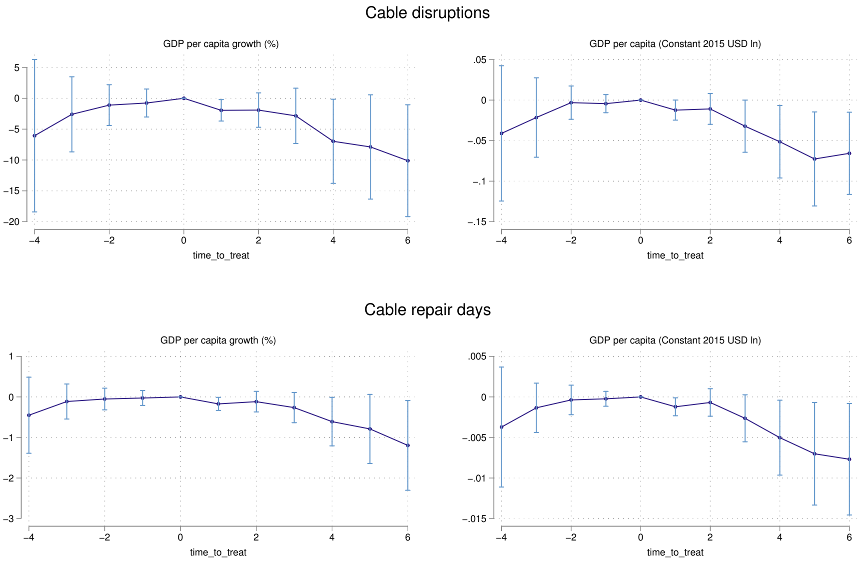

Fig. A.1.2.1 The growth costs of SMC failures: baseline specifications excluding income-by-year FEs.
Notes: Top row shows effects of cable disruptions on overall GDP growth (%, left) and log GDP per capita (center), and log GDP (right). Bottom row shows analogous effects for cable repair days. All panels report event–time coefficients with 95% confidence bands. Specifications include country fixed effects, year fixed effects, linear country trends, and region-by-year FEs, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

Table A.1.2.1 Treatment paths at estimation time-window [t-1; t+6]

	#Groups	%Groups	*year* 0	*year* 1	*year* 2	*year* 3	*year* 4	*year* 5 − 6 − 7
			Panel A. Cable disruptions					
Path 1	10	45.5	0	1	0	0	0	0
Path 2	3	13.6	0	2	0	0	0	0
Path 3	2	9.1	0	1	0	0	0	3
Path 4	2	9.1	0	1	0	0	0	4
Paths 5-9	5	22.7	–	–	–	–	–	–
			Panel A'. Cable disruptions - dropping 2020					
Path 1	9	56.25	0	1	0	0	0	0
Path 2	3	18.75	0	2	0	0	0	0
Path 3	1	6.25	0	1	0	0	0	3
Path 4	1	6.25	0	1	0	0	1	1
Path 5	1	6.25	0	1	2	0	0	1
Path 6	1	6.25	0	1	2	1	0	1
			Panel B. Cable repair days					
Path 1	4	20.8	0	1	0	0	0	0
Path 2	2	8.3	0	10	0	0	0	0
Path 3	2	8.3	0	16	0	0	0	0
Path 4	1	4.2	0	0	0	0	0	34
Paths 5-18	13	58.4	–	–	–	–	–	–
			Panel B'. Cable repair days - dropping 2020					
Path 1	4	25	0	1	0	0	0	0
Path 2	2	12.5	0	10	0	0	0	0
Path 3	2	12.5	0	16	0	0	0	0
Path 4	1	6.25	0	7	0	0	4	1
Paths 5-11	7	44.75	–	–	–	–	–	–

Notes: Year 0 corresponds to the year before the disruption occurred. In panels A and B, 22 of 58 switchers have a fully-observed window of 6 post-treatment periods in the estimation sample. Interpretation of path 1, panel A: 45.5% of treated countries have a "one-off" break in the first treated year and then no additional breaks over the next 6 years.

Table A.1.2.2 Cable failures and GDP per. cap. growth (%): Event-study estimates and placebo tests

	Estimate	SE	LB CI	UB CI	N	Switchers
			Panel A: Cable disruptions			
			Event-study effects			
Effect_1	-1.950698	0.8796778	-3.674835	-0.2265612	392	58
Effect_2	-1.805730	1.2350040	-4.226293	0.6148332	364	58
Effect_3	-2.254004	1.8088430	-5.799271	1.2912630	289	42
Effect_4	-5.531820	2.3386700	-10.11553	-0.9481100	213	29
Effect_5	-6.063789	3.0920850	-12.12416	-0.0034144	198	27
Effect_6	-8.051168	3.3679690	-14.65227	-1.4500700	174	23
Effect_7	-9.112940	3.8034310	-16.56753	-1.6583530	150	22
	Test of joint nullity of the effects: p-value = 0.02957928					
			Placebo leads			
Placebo_1	0.0886296	0.9583748	-1.789751	1.967010	360	55
Placebo_2	-0.1293523	1.2975970	-2.672597	2.413892	282	49
Placebo_3	-0.7202078	1.9900810	-4.620696	3.180280	196	31
Placebo_4	-1.4702760	3.4537230	-8.239448	5.298897	70	13
Placebo_5	2.6136940	3.6681070	-4.575664	9.803052	21	6
	Test of joint nullity of the placebos: p-value = 0.86895659					
			Panel B: Cable repair days			
			Event-study effects			
Effect_1	-0.166887	0.0826055	-0.3287907	-0.0049833	378	54
Effect_2	-0.1163032	0.1107374	-0.3333444	0.1007381	353	54
Effect_3	-0.2023648	0.1438693	-0.4843435	0.0796138	277	38
Effect_4	-0.4785969	0.209545	-0.8892974	-0.0678963	211	28
Effect_5	-0.6057429	0.3134311	-1.220057	0.0085707	199	26
Effect_6	-0.9583649	0.4037035	-1.749609	-0.1671205	175	22
Effect_7	-0.9759625	0.4158666	-1.791046	-0.160879	155	22
	Test of joint nullity of the effects: p-value = 0.01991066					
			Placebo leads			
Placebo_1	0.0491271	0.0739607	-0.0958332	0.1940875	346	51
Placebo_2	0.0235962	0.0976396	-0.1677739	0.2149664	271	45
Placebo_3	0.121817	0.1138709	-0.1940716	0.2522943	184	27
Placebo_4	-0.3021379	0.2568059	-0.6251473	0.3815134	67	12
Placebo_5	0.3021379	0.4874179	-0.6531836	1.257459	19	5
	Test of joint nullity of the placebos: p-value = 0.66211585					

Table A.1.2.3 Cable failures and GDP per. cap. (const USD, ln): Event-study estimates and placebo tests

	Estimate	SE	LB CI	UB CI	N	Switchers
	Panel A: Cable disruptions					
	Event-study effects					
Effect_1	-0.0160841	0.0062813	-0.0283953	-0.0037729	391	58
Effect_2	-0.0256202	0.0094812	-0.0438430	-0.0066775	363	58
Effect_3	-0.0228331	0.0116031	-0.0451871	-0.0009575	289	42
Effect_4	-0.0553423	0.0192004	-0.0929745	-0.0177102	213	29
Effect_5	-0.0730016	0.0265307	-0.1250008	-0.0210024	198	27
Effect_6	-0.0833617	0.0318762	-0.1458380	-0.0208854	174	23
Effect_7	-0.0938445	0.0383056	-0.1689220	-0.0187669	150	22
	Test of joint nullity of the effects: p-value = 0.00464478					
	Placebo leads					
Placebo_1	-0.0024135	0.0053333	-0.0128665	0.0080395	359	55
Placebo_2	-0.0035723	0.0110163	-0.0251637	0.0180192	281	49
Placebo_3	0.0017157	0.0154682	-0.0286014	0.0320327	196	31
Placebo_4	0.0285196	0.0361300	-0.0398089	0.0429297	70	13
Placebo_5	0.0121075	0.0593467	-0.1042099	0.1284249	21	6
	Test of joint nullity of the placebos: p-value = 0.71364384					
	Panel B: Cable repair days					
	Event-study effects					
Effect_1	-0.0014357	0.0006021	-0.0026157	-0.0002557	382	56
Effect_2	-0.0018819	0.0008908	-0.0032678	-0.0003160	357	56
Effect_3	-0.0016615	0.0012616	-0.0040891	0.0008561	282	40
Effect_4	-0.0038174	0.0019629	-0.0076466	0.0000298	216	30
Effect_5	-0.0054685	0.0030426	-0.0114319	0.0004948	203	28
Effect_6	-0.0069178	0.0042630	-0.0152732	0.0014376	179	24
Effect_7	-0.0070662	0.0045473	-0.0159788	0.0018465	159	24
	Test of joint nullity of the effects: p-value = 0.03589684					
	Placebo leads					
Placebo_1	-0.0001192	0.0004355	-0.0009727	0.0007343	347	52
Placebo_2	-0.0005187	0.0009488	-0.0023783	0.0013410	272	46
Placebo_3	-0.0005669	0.0013133	-0.0031409	0.0020070	186	28
Placebo_4	0.0032949	0.0029541	-0.0090848	0.0024949	69	13
Placebo_5	-0.0005277	0.0076471	-0.0144602	0.0155157	19	5
	Test of joint nullity of the placebos: p-value = 0.58428955					

Table A.1.2.4 Cable failures and GDP per. cap. (const USD, ln): Average effects

	Coef.	Std. Err.	z	p-value	95% CI
	Panel A: Cable disruptions				
avg_1_7	-4.967164	2.139255	-2.32	0.020	[−9.160027, −0.774301]
avg_2_7	-5.469909	2.397316	-2.28	0.023	[−10.16856, −0.771256]
avg_3_7	-6.202744	2.714713	-2.28	0.022	[−11.52348, −0.882004]
avg_4_7	-7.189929	3.041804	-2.36	0.018	[−13.15176, −1.228103]
avg_5_7	-7.742632	3.319909	-2.33	0.020	[−14.24795, −1.237317]
	Panel B: Cable repair days				
avg_1_7	-0.491728	0.219293	-2.24	0.025	[−0.921536, −0.061920]
avg_2_7	-0.545136	0.246465	-2.21	0.027	[−1.028199, −0.062072]
avg_3_7	-0.629804	0.279791	-2.25	0.024	[−1.178184, −0.081425]
avg_4_7	-0.735498	0.317037	-2.32	0.020	[−1.356879, −0.114117]
avg_5_7	-0.825086	0.356996	-2.31	0.021	[−1.524578, −0.125360]

Table A.1.2.5 Cable failures and GDP per. cap. growth (%), excluding region-by-year FEs: Event-study estimates and placebo tests

	Estimate	SE	LB CI	UB CI	N	Switchers
Panel A: Cable disruptions						
Event-study effects						
Effect_1	-1.224634	0.7492979	-2.693231	0.2439628	934	60
Effect_2	-1.448237	1.1043490	-3.612720	0.7162467	896	60
Effect_3	-1.374346	1.3838870	-4.086715	1.3380240	752	44
Effect_4	-4.457434	2.2467900	-8.861062	-0.0538070	660	30
Effect_5	-4.885011	2.8954640	-10.56001	0.7899936	554	28
Effect_6	-6.537678	2.9701560	-12.35908	-0.7162794	429	24
Effect_7	-6.900807	3.0939490	-12.96484	-0.8367783	390	23
Test of joint nullity of the effects: p-value = 0.12817						
Placebo leads						
Placebo_1	-0.2002856	0.7701497	-1.709751	1.309180	882	57
Placebo_2	0.0348312	0.9183815	-1.765163	1.834826	749	51
Placebo_3	-0.3929639	1.3068330	-2.954309	2.168382	594	33
Placebo_4	-1.8428420	2.8909710	-7.509042	3.823357	378	14
Test of joint nullity of the placebos: p-value = 0.94817						
Panel B: Cable repair days						
Event-study effects						
Effect_1	-0.0962363	0.0728768	-0.2390722	0.0465996	925	56
Effect_2	-0.0876711	0.1014472	-0.2865039	0.1111618	891	56
Effect_3	-0.1538398	0.1226799	-0.3942881	0.0866085	747	40
Effect_4	-0.3926938	0.1907398	-0.7665370	-0.0188506	660	29
Effect_5	-0.4964478	0.2739166	-1.0333140	0.0404189	556	27
Effect_6	-0.7943650	0.3297906	-1.4407430	-0.1479874	431	23
Effect_7	-0.7648841	0.3239352	-1.3997850	-0.1299828	400	23
Test of joint nullity of the effects: p-value = 0.14102						
Placebo leads						
Placebo_1	0.0170435	0.0581447	-0.0969181	0.1310050	873	53
Placebo_2	0.0240881	0.0856952	-0.1438715	0.1920476	744	47
Placebo_3	0.0202904	0.1040184	-0.1835819	0.2241626	589	29
Placebo_4	-0.1545479	0.2283079	-0.6020231	0.2929274	377	13
Test of joint nullity of the placebos: p-value = 0.72843						

Notes: Estimates from the baseline event-study specification re-estimated without region-by-year fixed effects (income-group-by-year fixed effects retained). All specifications include country fixed effects, year fixed effects, linear country trends, and income-group-by-year fixed effects, with standard errors clustered at the country level. F-tests are computed under `effects(7)`.

Table A.1.2.6 Cable failures and GDP per. cap. (const USD, ln), excluding region-by-year FEs: Event-study estimates and placebo tests

	Estimate	SE	LB CI	UB CI	N	Switchers
Panel A: Cable disruptions						
Event-study effects						
Effect_1	-0.0095209	0.0062256	-0.0217228	0.0026809	884	59
Effect_2	-0.0105136	0.0102868	-0.0306754	0.0096482	748	44
Effect_3	-0.0266178	0.0133292	-0.0527425	-0.0004932	654	30
Effect_4	-0.0452971	0.0181853	-0.0809396	-0.0096547	543	28
Effect_5	-0.0658371	0.0256377	-0.1160861	-0.0155881	436	24
Effect_6	-0.0638901	0.0251056	-0.1130962	-0.0146840	398	23
Effect_7	-0.0691478	0.0303987	-0.1287282	-0.0095674	328	22
Test of joint nullity of the effects (`effects(6)`)*:* p-value = 0.11908						
Placebo leads						
Placebo_1	-0.0008711	0.0045311	-0.0097518	0.0080097	835	56
Placebo_2	0.0036298	0.0092456	-0.0144913	0.0217508	608	35
Placebo_3	-0.0079164	0.0222230	-0.0514726	0.0356398	503	19
Placebo_4	-0.0255676	0.0356369	-0.0954146	0.0442794	275	12
Test of joint nullity of the placebos: p-value = 0.71588						
Panel B: Cable repair days						
Event-study effects						
Effect_1	-0.0007224	0.0005846	-0.0018682	0.0004234	875	55
Effect_2	-0.0002797	0.0009233	-0.0020893	0.0015299	740	40
Effect_3	-0.0021465	0.0013917	-0.0048742	0.0005812	649	29
Effect_4	-0.0043449	0.0021470	-0.0085530	-0.0001368	541	27
Effect_5	-0.0062435	0.0030187	-0.0121600	-0.0003270	435	23
Effect_6	-0.0073223	0.0035149	-0.0142113	-0.0004333	406	23
Effect_7	-0.0070526	0.0036976	-0.0142998	0.0001945	336	22
Test of joint nullity of the effects (`effects(6)`)*:* p-value = 0.01381						
Placebo leads						
Placebo_1	0.0000049	0.0003905	-0.0007605	0.0007702	826	52
Placebo_2	0.0000692	0.0008966	-0.0016881	0.0018264	600	31
Placebo_3	-0.0006697	0.0016061	-0.0038176	0.0024781	498	18
Placebo_4	-0.0027016	0.0036506	-0.0098566	0.0044534	272	11
Test of joint nullity of the placebos: p-value = 0.79870						

Notes: Estimates from the baseline event-study specification re-estimated without region-by-year fixed effects (income-group-by-year fixed effects retained). All specifications include country fixed effects, year fixed effects, linear country trends, and income-group-by-year fixed effects, with standard errors clustered at the country level. F-tests are reported from the `effects(6)` specification, as the `effects(7)` F-test for estimations using GDP per capita in level is flagged unreliable (near-singular variance matrix).

A.1.3 Leave-one-out robustness

To assess whether the headline estimates are driven by any single influential switcher, I re-estimate each baseline event-study sequentially excluding each treated country from the estimation sample. The resulting distribution of point estimates at horizons $t+5$ and $t+6$ is reported below for four key outcomes: GDP per capita growth (baseline specification, Figure A.1.3.1), log GDP per capita (baseline, Figure A.1.3.2; and broader counterfactual without region-by-year fixed effects, Figure A.1.3.3), and log goods-and-services imports per capita which displays the highest sensitivity (-65%) to cable breaks (mechanism-section specification, Figure A.1.3.4). Across all four outcomes, point estimates remain negative across the entire leave-one-out (LOO) distribution; the headline magnitudes are robust in sign and order of magnitude to any single-country exclusion. The most influential switcher varies by outcome—Armenia, Liberia, or Sierra Leone for the GDP outcomes; Sudan for the import channel—but no single exclusion moves the point estimate outside the full-sample 95% confidence band.

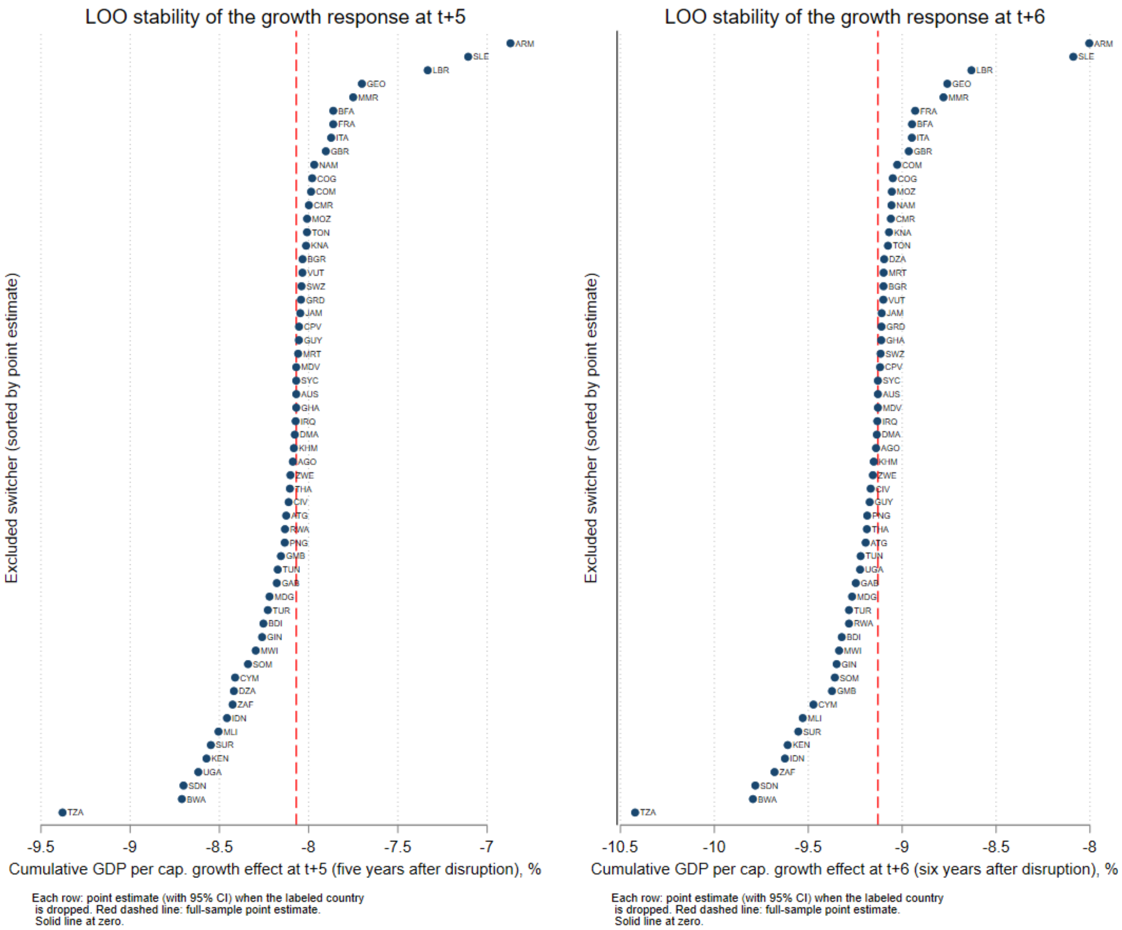

Fig. A.1.3.1 Leave-one-out stability: GDP per capita growth response (baseline specification).
Notes: Each row reports the estimated effect at $t+5$ (left panel) or $t+6$ (right panel) from a leave-one-out re-estimation of the baseline event-study in which the labeled country is excluded from the sample. Red dashed line: full-sample point estimate; solid vertical line: zero. Specification follows Figure 3 (treatment: `cable_disrupt`; country, year, country-trend, region-by-year, and income-group-by-year fixed effects; standard errors clustered at the country level).

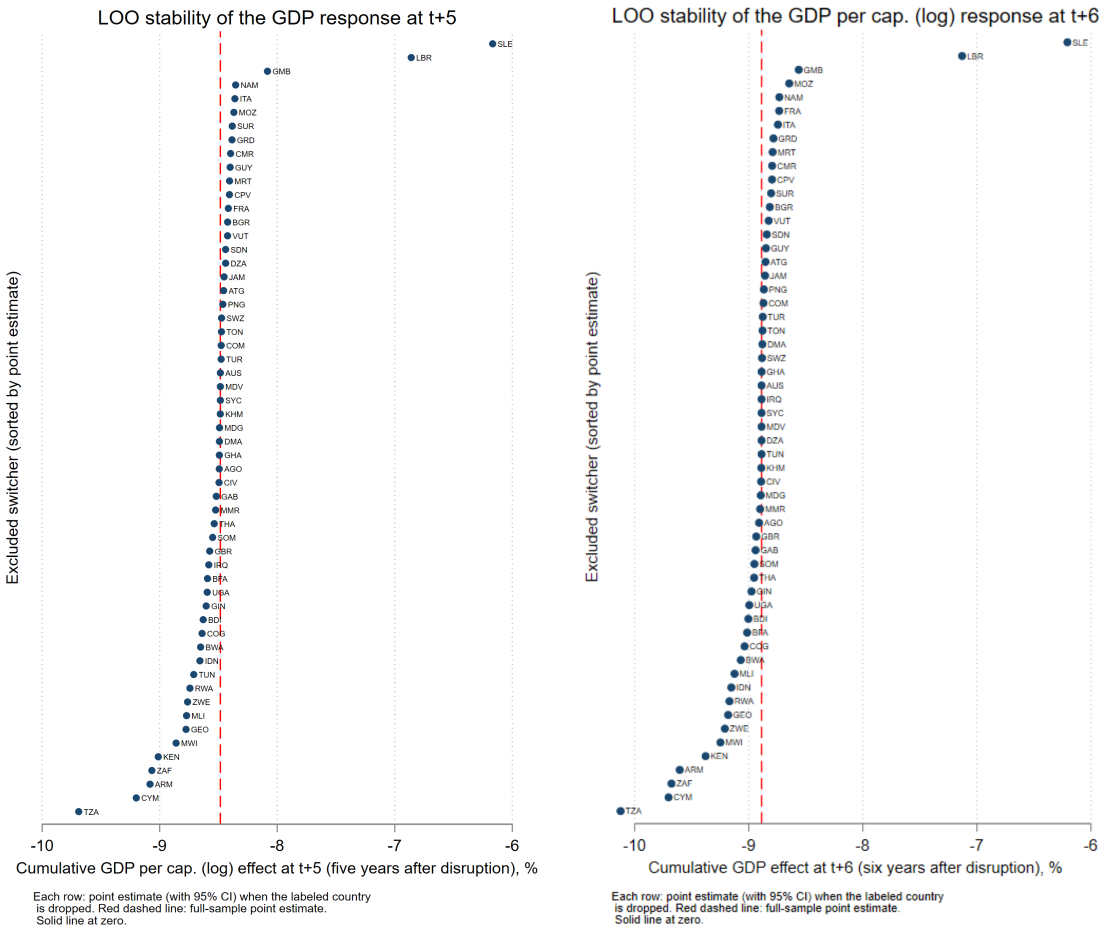

Fig. A.1.3.2 Leave-one-out stability: log GDP per capita response (baseline specification).

Notes: Each row reports the estimated cumulative deviation in log GDP per capita at $t+5$ (left panel) or $t+6$ (right panel) from a leave-one-out re-estimation of the baseline event-study in which the labeled country is excluded from the sample. Red dashed line: full-sample point estimate; solid vertical line: zero. Specification follows Figure 3 (treatment: `cable_disrupt`).

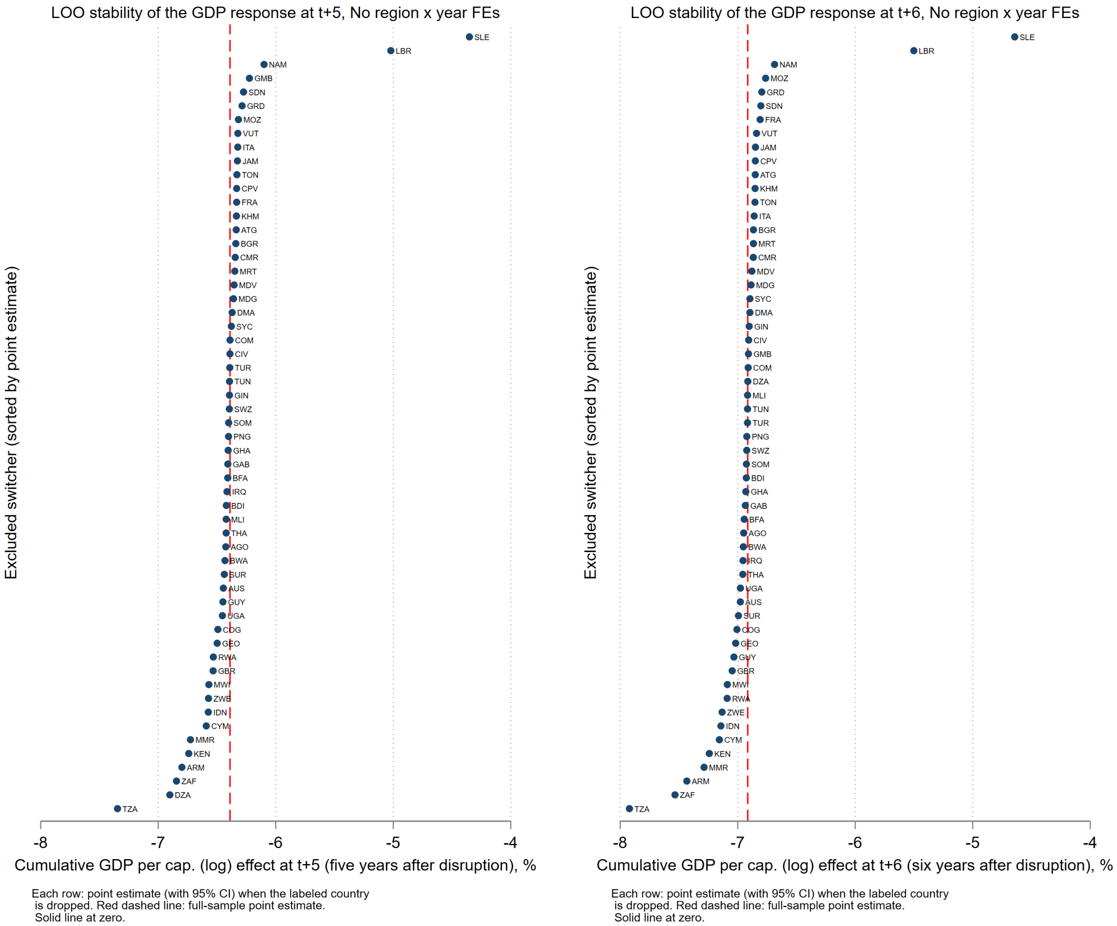

Fig. A.1.3.3 Leave-one-out stability: log GDP per capita response, broader counterfactual (no region-by-year FE).

Notes: Each row reports the estimated cumulative deviation in log GDP per capita at $t+5$ (left panel) or $t+6$ (right panel) from a leave-one-out re-estimation of the broader-counterfactual event-study (region-by-year fixed effects dropped) in which the labeled country is excluded from the sample. Red dashed line: full-sample point estimate; solid vertical line: zero. Specification follows Figure 4 (treatment: `cable_disrupt`).

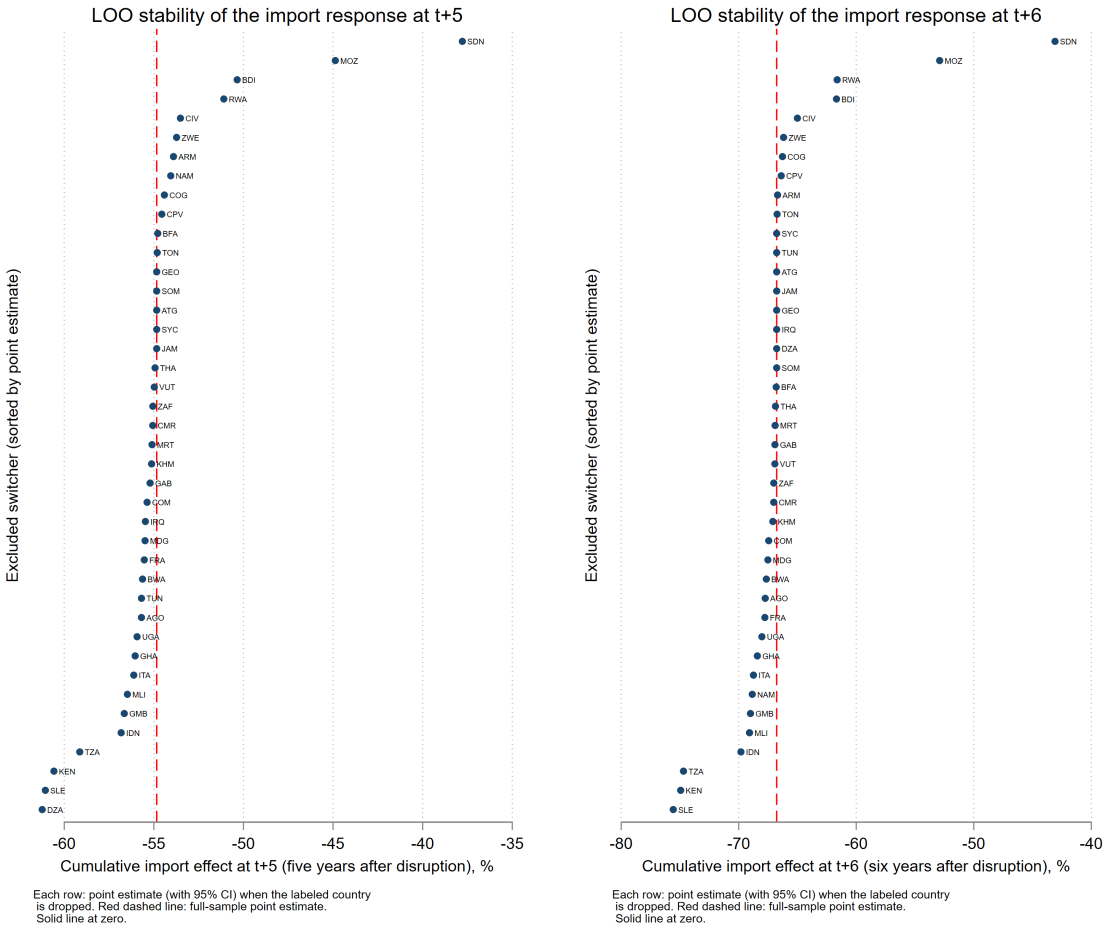

Fig. A.1.3.4 Leave-one-out stability: cumulative goods-and-services import response.

Notes: Each row reports the estimated cumulative deviation in log goods-and-services imports per capita at t+5 (left panel) or t+6 (right panel) from a leave-one-out re-estimation in which the labeled country is excluded from the sample. Treatment: `cable_break` (mechanism-section convention). Red dashed line: full-sample point estimate; solid vertical line: zero.

A.1.4 Subtel Forum *versus* Cloudflare data

Table A.1.4.1 Correlation between SubTel disruption exposure and Cloudflare nationwide cable-cut events

Dep. var: Cloudflare disruptions	(1)	(2)	(3)
	Panel A: Affected and non affected countries (109 obs)		
Subtel disruptions	4.213**	4.201**	2.594*
	(1.115)	(1.129)	(1.189)
ln GDP per cap		-0.0571	
		(0.0448)	
Internet users (% pop)			-0.0206***
			(0.0046)
Observations	109	109	104
R-squared	0.364	0.371	0.463
	Panel B: Affected countries (41 obs)		
Subtel disruptions	3.170**	3.413**	2.530*
	(1.237)	(1.277)	(1.345)
ln(GDP)		-0.145	
		(0.112)	
internet_users_pct			-0.0186***
			(0.00581)
Observations	41	41	40
R-squared	0.2697	0.2987	0.3765
HDFE absorbed	Yes	Yes	Yes

Notes: Each column reports an OLS regressions with robust standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$. The dependent variable *Cloudflare disruptions*is the cumulated sum of cable disruption events detected by the Cloudflare Radar from 2022 to 2025. The interest variable *Subtel disruptions* is the average number of cable disruption events reported by Subtelforum from 2015 to 2019. Panel A include countries in the baseline sample not affected by cable disruptions according to the Cloudflare Radar (counted as 0). Panel B is restricted to countries affected by at least one cable disruptions according to the Cloudflare Radar. Results are robust to the use of the Poisson estimator (available on request).

Table A.1.4.2 Subtel vs Cloudflare data - Sample composition , $N = 109$

ISO	%	Cum.	ISO	%	Cum.	ISO	%	Cum.
AFG	0.92	0.92	GMB	0.92	33.94	NGA	0.92	66.97
AGO	0.92	1.83	GRD	0.92	34.86	NOR	0.92	67.89
ARE	0.92	2.75	GRL	0.92	35.78	NZL	0.92	68.81
ARG	0.92	3.67	GUY	0.92	36.70	OMN	0.92	69.72
ARM	0.92	4.59	HKG	0.92	37.61	PAK	0.92	70.64
AUS	0.92	5.50	HND	0.92	38.53	PAN	0.92	71.56
BDI	0.92	6.42	HTI	0.92	39.45	PHL	0.92	72.48
BEN	0.92	7.34	IDN	0.92	40.37	PLW	0.92	73.39
BFA	0.92	8.26	IND	0.92	41.28	PNG	0.92	74.31
BGD	0.92	9.17	IRL	0.92	42.20	PRI	0.92	75.23
BHR	0.92	10.09	IRQ	0.92	43.12	PRT	0.92	76.15
BRA	0.92	11.01	ISR	0.92	44.04	PRY	0.92	77.06
BRB	0.92	11.93	ITA	0.92	44.95	RUS	0.92	77.98
BWA	0.92	12.84	JAM	0.92	45.87	RWA	0.92	78.90
CAN	0.92	13.76	JPN	0.92	46.79	SDN	0.92	79.82
CHE	0.92	14.68	KAZ	0.92	47.71	SEN	0.92	80.73
CHL	0.92	15.60	KEN	0.92	48.62	SLB	0.92	81.65
CHN	0.92	16.51	KGZ	0.92	49.54	SLE	0.92	82.57
CIV	0.92	17.43	KNA	0.92	50.46	SEN	0.92	80.73
CMR	0.92	18.35	LBN	0.92	51.38	SOM	0.92	83.49
COG	0.92	19.27	LBR	0.92	52.29	SWE	0.92	84.40
COL	0.92	20.18	LBY	0.92	53.21	SWZ	0.92	85.32
COM	0.92	21.10	LKA	0.92	54.13	TCD	0.92	86.24
CUB	0.92	22.02	MAR	0.92	55.05	TGO	0.92	87.16
CZE	0.92	22.94	MDA	0.92	55.96	THA	0.92	88.07
DZA	0.92	23.85	MDG	0.92	56.88	TJK	0.92	88.99
ECU	0.92	24.77	MDV	0.92	57.80	TKM	0.92	89.91
EGY	0.92	25.69	MEX	0.92	58.72	TON	0.92	90.83
ESP	0.92	26.61	MKD	0.92	59.63	TUN	0.92	91.74
FIN	0.92	27.52	MMR	0.92	60.55	TUR	0.92	92.66
FRA	0.92	28.44	MOZ	0.92	61.47	TZA	0.92	93.58
GAB	0.92	29.36	MRT	0.92	62.39	UGA	0.92	94.50
GBR	0.92	30.28	MWI	0.92	63.30	UKR	0.92	95.41
GEO	0.92	31.19	MYS	0.92	64.2	USA	0.92	96.33
GHA	0.92	32.11	NAM	0.92	65.14	UZB	0.92	97.25
GIN	0.92	33.03	NER	0.92	66.06	VCT	0.92	98.17
						VUT	0.92	99.08
						ZAF	0.92	100.00

A.1.5 Regional spillovers

Table A.1.5.1 Regional peer disruptions: Event-study estimates and placebo tests

	Estimate	SE	LB CI	UB CI	N	Switchers
Panel A: Regional number of disrupted economies - with income-group×year FEs						
Event-study effects						
Effect_1	1.3014430	0.4078092	0.5021521	2.1007350	76	56
Effect_2	0.9219763	0.4834319	-0.0255328	1.8694850	74	54
Effect_3	0.9616457	0.6312889	-0.2756578	2.1989490	75	54
Effect_4	0.1886195	0.9474062	-1.6682620	2.0455020	44	39
Effect_5	0.7666671	1.0758510	-1.3419620	2.8752960	44	39
Effect_6	1.1972540	1.1752930	-1.1062770	3.5007860	45	39
Effect_7	1.0734810	1.0934610	-1.0696630	3.2166260	44	39
Test of joint nullity of the effects: p-value = 1.067×10^{-6}						
Placebo leads						
Placebo_1	0.1722157	0.7412890	-1.2806840	1.6251150	15	11
Placebo_2	-0.2504074	1.1070470	-2.4201810	1.9193660	15	11
Placebo_3	-1.0963900	1.2885600	-3.6219220	1.4291420	16	11
Test of joint nullity of the placebos: p-value = 0.1120273						
Panel B: Regional number of disrupted economies - no income-group×year FEs						
Event-study effects						
Effect_1	0.7381727	0.3508080	0.0506017	1.4257440	117	78
Effect_2	0.6197269	0.4434851	-0.2494880	1.4889420	115	76
Effect_3	0.5749558	0.5184753	-0.4412370	1.5911490	118	76
Effect_4	1.2246190	0.7023941	-0.1520478	2.6012860	80	73
Effect_5	1.5344730	0.8553296	-0.1419421	3.2108880	80	73
Effect_6	2.1583460	0.9441810	0.3077856	4.0089070	83	73
Effect_7	1.7404470	0.7475975	0.2751825	3.2057110	78	71
Test of joint nullity of the effects: p-value = 0.00001842						
Placebo leads						
Placebo_1	0.4900590	0.5729660	-0.6329336	1.6130520	37	33
Placebo_2	0.2651264	0.8856412	-1.4706980	2.0009510	37	33
Placebo_3	-0.5364274	1.0230560	-2.5415810	1.4687260	40	33
Test of joint nullity of the placebos: p-value = 0.10079289						
Panel C: Regional number of disruption episodes - with income-group×year FEs						
Event-study effects						
Effect_1	2.7292400	0.8552116	1.0530570	4.4054240	76	56
Effect_2	1.9342160	1.0141930	-0.0535653	3.9219970	74	54
Effect_3	2.0174380	1.3243820	-0.5783033	4.6131800	75	54
Effect_4	0.3966839	1.9924830	-3.5085110	4.3018790	44	39
Effect_5	1.6123710	2.2626140	-2.8222710	6.0470140	44	39
Effect_6	2.5179360	2.4717500	-2.3266050	7.3624760	45	39
Effect_7	2.2314890	2.2730220	-2.2235530	6.6865300	44	39
Test of joint nullity of the effects: p-value = 1.067×10^{-6}						
Placebo leads						
Placebo_1	0.4767450	2.0526811	-3.5465100	4.5000000	15	11
Placebo_2	-0.7802710	3.3062607	-7.2605420	5.7000000	15	11
Placebo_3	-3.3328800	3.8427959	-10.8657600	4.2000000	16	11
Test of joint nullity of the placebos: p-value = 0.11202698						
Panel D: Regional number of disruption episodes - no income-group×year FEs						
Event-study effects						
Effect_1	1.6480130	0.7831992	0.1129710	3.1800000	117	78
Effect_2	1.3916680	0.9958964	-0.5602536	3.3435896	115	76
Effect_3	1.2911290	1.1642950	-0.9908477	3.5731057	118	76
Effect_4	2.6802980	1.5373150	-0.3327847	5.6933807	80	73
Effect_5	3.3584680	1.8720420	-0.3106665	7.0276025	80	73
Effect_6	4.7239270	2.0665090	0.6736429	8.7742111	83	73
Effect_7	3.6831030	1.5820530	0.5823363	6.7838697	78	71
Test of joint nullity of the effects: p-value = 0.00001843						
Placebo leads						
Placebo_1	-3.6763695	4.1205967	-11.7527390	4.4000000	37	33
Placebo_2	0.7939525	2.6561467	-4.4120950	6.0000000	37	33
Placebo_3	-1.6123715	3.0675365	-7.6247430	4.4000000	40	33
Test of joint nullity of the placebos: p-value = 0.10079309						

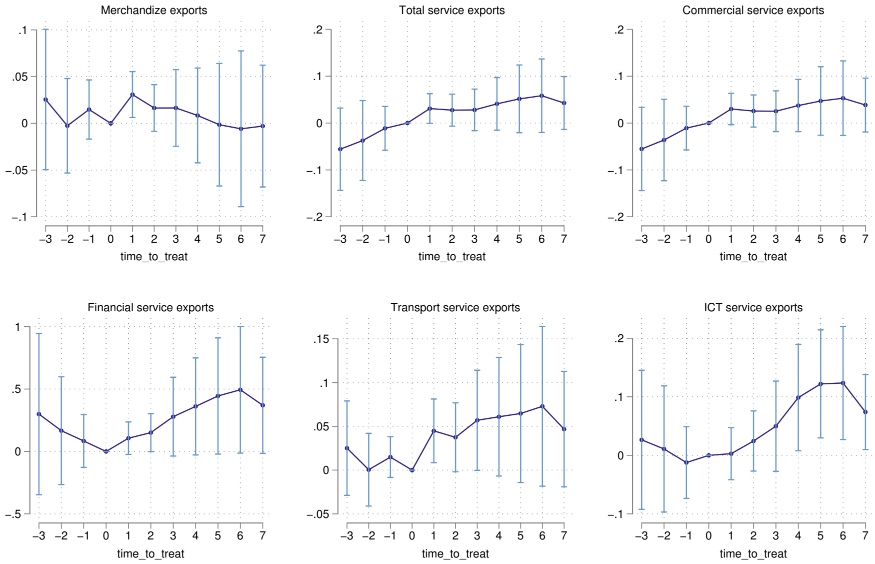

Fig. A.1.5.1 Regional spillovers on exports (USD, ln) - regional number of affected countries.

Notes: Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, and linear country trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence. The treatment is the number of affected economies recorded in the region of the non-affected country.

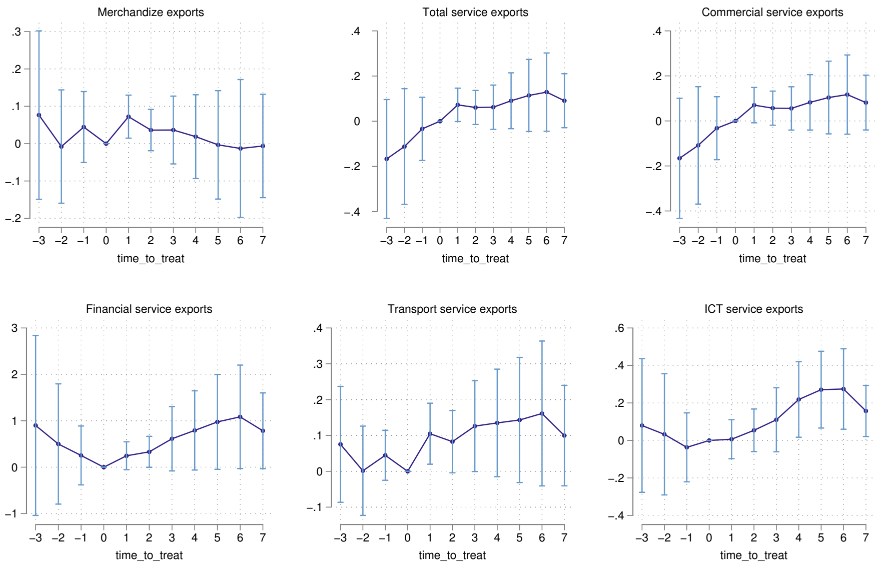

Fig. A.1.5.2 Regional spillovers on exports (USD, ln) - regional number of disruption episodes.

Notes: Figures report event–time coefficients with 95% confidence bands; specifications include country fixed effects, year fixed effects, and linear country trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence. The treatment is the number of cable disruptions recorded in the region of the non-affected country.

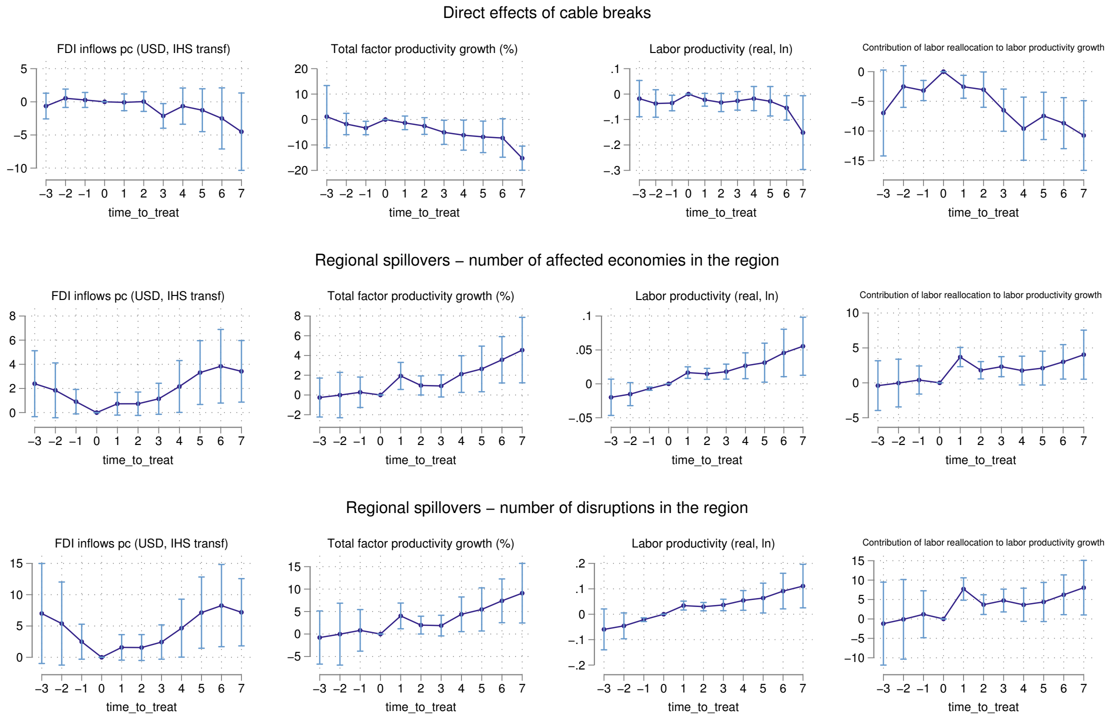

Fig. A.1.5.3 Cable breaks and competitiveness, direct effects and regional spillovers.

Notes: Figures report event–time coefficients with 90% confidence bands. All specifications include at least country fixed effects, year, and *income group* × *year* fixed effects, a linear country trends, with standard errors clustered at the country level. Top-row graphs include *region* × *years* fixed effects. FDI inflows per capita are transformed using the inverse hyperbolic sine. Labor productivity levels are measured as real GDP in US dollars measured in 2010 prices and exchange rates, divided by employment. TFP is a Human capital-adjusted TFP growth metric, calculated as a residual of labor productivity growth by subtracting the contribution of human capital and capital deepening to labor productivity growth. Year 7 corresponds to a period of six years after the cable failure occurrence. The regional treatment is either the number of affected economies or the number of disruptions –since one disruption can affect multiple economies– recorded in the region of the non-affected country.

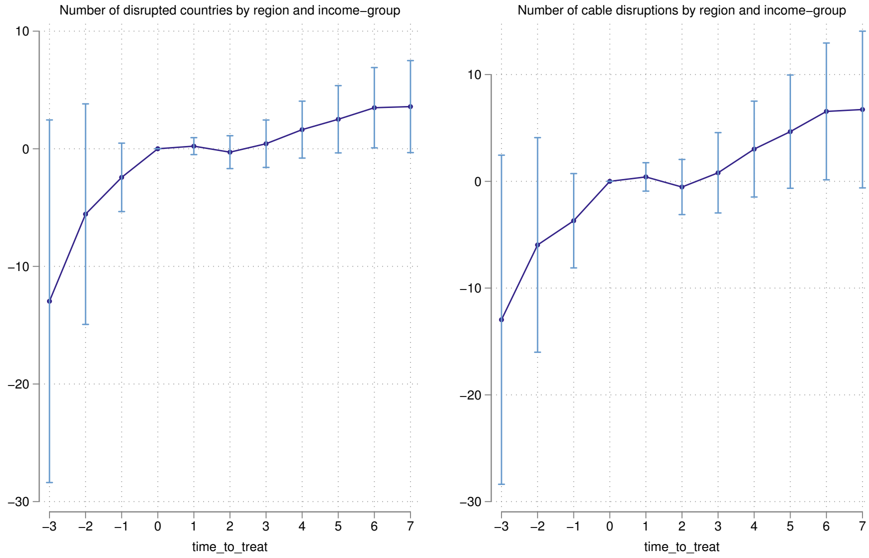

Fig. A.1.5.4 Regional–income group spillovers on per capita growth rates.

Notes: Figures report event–time coefficients with 90% confidence bands; all specifications include at least country fixed effects, year fixed effects, $income - group \times year$ fixed effects, a linear country trend, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence. The regional treatment is either the number of affected economies or the number of disruptions –since one disruption can affect multiple economies– recorded in the region-income-group of the non-affected country. When using the regional-by-income-group number of affected economies, the sample consist of 199 never-switchers (34 countries) and 971 (84) switcher-in countries. When using the regional-by-income-group number of cable disruption episodes, the sample consist of 206 never-switchers (41 countries) and 971 (84) switcher-in countries.

A.1.6 Exposure factors: detailed estimates and additional estimations

Table A.1.6.1 Exposure factor: cable density - Dep. var: GDP per capita (cst USD, ln)

	Estimate	SE	LB CI	UB CI	N	Switchers
			Panel A: Cable disruptions			
Event-study effects, countries with less than 2 SMCs at baseline						
Effect_1	-0.016151	0.0077128	-0.031732	-0.0014982	277	48
Effect_2	-0.015491	0.0127912	-0.0405615	0.0095792	213	34
Effect_3	-0.043123	0.0169108	-0.0762769	-0.0099877	159	23
Effect_4	-0.0609051	0.0215189	-0.1030814	-0.0187288	135	22
Effect_5	-0.0953038	0.0375909	-0.1689807	-0.0216269	118	18
Effect_6	-0.0913442	0.0376943	-0.1652237	-0.0174646	105	17
Effect_7	-0.0948740	0.0422522	-0.1776868	-0.0120611	89	17
	Test of joint nullity of the effects: p-value = 0.09697087					
Placebo leads						
Placebo_1	-0.0043465	0.006149	-0.0163984	0.0077054	277	48
Placebo_2	0.0017591	0.0123483	-0.0224432	0.0259613	166	28
Placebo_3	0.0126587	0.0308894	-0.0732008	0.0478834	101	15
Placebo_4	-0.0326342	0.0507389	-0.1320806	0.0668122	43	9
	Test of joint nullity of the placebos: p-value = 0.79889347					
Event-study effects, countries with more than 2 SMCs at baseline						
Effect_1	-0.0047134	0.0069626	-0.0183598	0.0089331	31	7
Effect_2	-0.0089523	0.0117188	-0.0319208	0.0140161	29	6
Effect_3	-0.0150795	0.0208495	-0.0559438	0.0257848	24	6
Effect_4	0.0357675	0.0307084	-0.0960205	0.0246676	21	5
Effect_5	-0.0511884	0.0394048	-0.1284204	0.0260436	21	5
Effect_6	-0.0508085	0.0366205	-0.1225834	0.0209663	21	5
Effect_7	-0.1056703	0.0985599	-0.2988441	0.0875036	17	3
	Test of joint nullity of the effects: p-value = 0.55676114					
Placebo leads						
Placebo_1	-0.0180623	0.0129461	-0.0434362	0.0073116	14	4
Placebo_2	-0.0110334	0.0091271	-0.0289222	0.0068554	14	4
Placebo_3	-0.0238910	0.0204706	-0.0640127	0.0162307	7	3
Placebo_4	-0.0279690	0.0219853	-0.0710594	0.0151214	4	2
	Test of joint nullity of the placebos: p-value = 0.55604552					
			Panel B: Cable repair days			
Event-study effects, countries with less than 2 SMCs at baseline						
Effect_1	-0.001519	0.0007296	-0.0030218	-0.0001619	264	44
Effect_2	-0.001162	0.0011387	-0.0033939	0.0010698	201	30
Effect_3	-0.0036508	0.0019287	-0.0074310	0.0001293	153	22
Effect_4	-0.0056063	0.0025575	-0.0106189	-0.0005938	133	21
Effect_5	-0.0084040	0.0041259	-0.0164905	-0.0003175	117	17
Effect_6	-0.0098397	0.0049180	-0.0194788	-0.0002006	109	17
Effect_7	-0.0096833	0.0049906	-0.0194647	-0.0000980	93	17
	Test of joint nullity of the effects: p-value = 0.00767882					
Placebo leads						
Placebo_1	-0.0002204	0.0004972	-0.0011949	0.0007541	264	44
Placebo_2	-0.0001944	0.0011585	-0.0024649	0.0020762	154	24
Placebo_3	0.0013185	0.0022234	-0.0056763	0.0030394	95	14
Placebo_4	-0.0035647	0.0046860	-0.0127490	0.0056196	40	8
	Test of joint nullity of the placebos: p-value = 0.88315022					
Event-study effects, with more than 2 SMCs at baseline						
Effect_1	-0.0001899	0.0003995	-0.0009730	0.0005932	33	8
Effect_2	0.0002654	0.0011936	-0.0020740	0.0026049	33	8
Effect_3	0.0010651	0.0023863	-0.0036119	0.0057421	26	7
Effect_4	0.0021075	0.0056481	-0.0090525	0.0130875	23	6
Effect_5	0.0025431	0.0076081	-0.0123684	0.0174547	23	6
Effect_6	0.0030162	0.0086911	-0.0138722	0.0210961	23	6
Effect_7	0.0085037	0.0155296	-0.0219338	0.0389412	19	4
	Test of joint nullity of the effects: p-value = 0.63489944					
Placebo leads						
Placebo_1	-0.0007526	0.0005394	-0.0018098	0.0003047	14	4
Placebo_2	-0.0006755	0.0005588	-0.0017707	0.0004197	14	4
Placebo_3	0.0012315	0.0010552	-0.0032996	0.0008366	7	3
Placebo_4	-0.0030327	0.0023768	-0.0076821	0.0016347	4	2
	Test of joint nullity of the placebos: p-value = 0.5560458					

Table A.1.6.2 Exposure factor: Connected partners - Dep. var: GDP per capita (cst USD, ln)

	Estimate	SE	LB CI	UB CI	N	Switchers
Panel A: Cable disruptions						
Event-study effects, countries with less than 10 connected partners at baseline						
Effect_1	-0.0178554	0.0083093	-0.0341413	-0.0015695	227	41
Effect_2	-0.0243052	0.0131066	-0.0500015	0.0013911	182	31
Effect_3	-0.0475558	0.0184210	-0.0833074	-0.0118041	130	21
Effect_4	-0.0650511	0.0236543	-0.1112402	-0.0180870	108	20
Effect_5	-0.1046329	0.0432699	-0.1894404	-0.0198254	92	16
Effect_6	-0.1303071	0.0446246	-0.2197697	-0.0158445	80	15
Effect_7	-0.1063543	0.0479341	-0.2038314	-0.0088772	66	15
Test of joint nullity of the effects: p-value = 0.19718756						
Placebo leads						
Placebo_1	-0.0037281	0.0057842	-0.0150649	0.0076088	227	41
Placebo_2	-0.0077203	0.0140648	-0.0358267	0.0198462	138	26
Placebo_3	-0.0318909	0.0337203	-0.0980716	0.0341097	76	14
Placebo_4	-0.0462155	0.0515078	-0.1471699	0.0540738	40	9
Test of joint nullity of the placebos: p-value = 0.90050126						
Event-study effects, countries with more than 10 connected partners at baseline						
Effect_1	-0.0129436	0.0105689	-0.0336582	0.0077111	49	13
Effect_2	0.0171878	0.0149755	-0.0121636	0.0465392	25	9
Effect_3	0.0364046	0.0211033	-0.0030501	0.0758593	22	8
Effect_4	0.0316143	0.0249748	-0.0173054	0.0805939	20	7
Effect_5	0.0261818	0.0293002	-0.0312456	0.0836092	19	7
Effect_6	0.0142449	0.0241369	-0.0330626	0.0615525	18	7
Effect_7	0.0421985	0.0406314	-0.0374377	0.1218346	13	5
Test of joint nullity of the effects: p-value = 0.08365044						
Placebo leads						
Placebo_1	-0.0052415	0.0108857	-0.0265209	0.0160379	40	10
Placebo_2	-0.0052151	0.0120235	-0.0183506	0.0278070	14	5
Placebo_3	0.0077719	0.0289499	-0.0489688	0.0645126	11	4
Placebo_4	-0.0276125	0.0271315	-0.0807893	0.0255643	7	2
Test of joint nullity of the placebos: p-value = 0.69661468						
Panel B: Cable repair days						
Event-study effects, countries with less than 10 connected partners at baseline						
Effect_1	-0.0014723	0.0077624	-0.0029666	0.0002221	219	39
Effect_2	-0.0014322	0.0123590	-0.0038545	0.0009901	175	29
Effect_3	-0.0040653	0.0211744	-0.0082153	0.0000847	125	20
Effect_4	-0.0060727	0.0284060	-0.0116402	-0.0000503	106	19
Effect_5	-0.0094042	0.0478740	-0.0187873	-0.0000211	91	15
Effect_6	-0.0110628	0.0570208	-0.0222754	-0.0001498	84	15
Effect_7	-0.0150554	0.0564610	-0.0215715	0.0005608	70	15
Test of joint nullity of the effects: p-value = 0.03613592						
Placebo leads						
Placebo_1	-0.000315	0.0005141	-0.0013226	0.0006926	219	39
Placebo_2	-0.0006576	0.0012866	-0.0031782	0.0018630	131	24
Placebo_3	-0.0026437	0.0025456	-0.0076330	0.0023456	71	13
Placebo_4	-0.0045599	0.0048876	-0.0114755	0.0049837	37	8
Test of joint nullity of the placebos: p-value = 0.81649942						
Event-study effects, countries with more than 10 connected partners at baseline						
Effect_1	-0.0009052	0.0010324	-0.0029287	0.0011183	48	13
Effect_2	0.0022539	0.0012231	-0.0001434	0.0046512	24	9
Effect_3	0.0039463	0.0021629	-0.0002929	0.0081555	24	9
Effect_4	0.0063482	0.0044160	-0.0023701	0.0150034	22	8
Effect_5	0.0072143	0.0058297	-0.0042117	0.0186403	22	8
Effect_6	0.0075111	0.0065138	-0.0052556	0.0202779	21	8
Effect_7	0.0131423	0.0130019	-0.0070490	0.0333337	15	6
Test of joint nullity of the effects: p-value = 0.15801121						
Placebo leads						
Placebo_1	0.0000621	0.0006754	-0.0012617	0.0013860	37	9
Placebo_2	-0.0002417	0.0007682	-0.0014774	0.0012639	11	4
Placebo_3	0.0003986	0.0014846	-0.0025112	0.0033083	11	4
Placebo_4	-0.0029851	0.0029331	-0.0087340	0.0027637	7	2
Test of joint nullity of the placebos: p-value = 0.73482839						

Table A.1.6.3 Exposure factor: IXPs - Dep. var: GDP per capita (cst USD, ln)

	Estimate	SE	LB CI	UB CI	N	Switchers
Panel A: Cable disruptions						
Event-study effects, countries with no IXP						
Effect_1	-0.0189173	0.0091647	-0.0368797	-0.0009549	202	39
Effect_2	-0.0191145	0.0155196	-0.0495324	0.0113034	153	28
Effect_3	-0.0689046	0.0333930	-0.1342484	-0.0035607	105	16
Effect_4	-0.0931563	0.0387908	-0.1695448	-0.0174877	93	16
Effect_5	-0.1834622	0.0789860	-0.3382539	-0.0286165	82	13
Effect_6	-0.1490254	0.0661469	-0.2786709	-0.0193798	74	13
Effect_7	-0.1554429	0.0791558	-0.3105854	-0.0003003	59	12
Test of joint nullity of the effects: p-value = 0.17107647						
Placebo leads						
Placebo_1	-0.0025691	0.0074703	-0.0172107	0.0120726	202	39
Placebo_2	-0.0015334	0.0163308	-0.0354112	0.0304743	131	25
Placebo_3	-0.0171764	0.0400308	-0.0956354	0.0612826	74	12
Placebo_4	-0.0450509	0.0572891	-0.1573354	0.0672336	38	8
Test of joint nullity of the placebos: p-value = 0.67173253						
Event-study effects, countries with at least 1 IXP						
Effect_1	-0.0028077	0.0067164	-0.0159716	0.0103562	54	14
Effect_2	-0.0084263	0.0123375	-0.0326073	0.0157547	50	12
Effect_3	-0.0141184	0.0155629	-0.0456211	0.0163843	47	11
Effect_4	-0.0173247	0.0204336	-0.0573737	0.0227244	41	9
Effect_5	-0.0148378	0.0264481	-0.0666751	0.0369994	40	9
Effect_6	-0.0170459	0.0248257	-0.0657033	0.0316116	40	9
Effect_7	-0.0032057	0.0275441	-0.0571912	0.0507798	36	8
Test of joint nullity of the effects: p-value = 0.13091225						
Placebo leads						
Placebo_1	0.0091365	0.0169671	-0.0241185	0.0423914	28	11
Placebo_2	-0.0171635	0.0181874	-0.0528103	0.0184832	18	6
Placebo_3	-0.0506292	0.0373045	-0.1237446	0.0224862	12	4
Placebo_4	0.0530124	0.0626209	-0.0697223	0.1757474	4	1
Test of joint nullity of the placebos: p-value = 0.19395334						
Panel B: Cable repair days						
Event-study effects, countries with no IXP						
Effect_1	-0.0016748	0.0008356	-0.0033125	-0.0000370	197	37
Effect_2	-0.0009885	0.0011474	-0.0038776	0.0019005	148	26
Effect_3	-0.0041464	0.0032831	-0.0105811	0.0022883	107	17
Effect_4	-0.0057256	0.0038017	-0.0133337	0.0018824	95	17
Effect_5	-0.0098580	0.0073032	-0.0236807	0.0038891	85	14
Effect_6	-0.0110500	0.0082536	-0.0272268	0.0051269	77	14
Effect_7	-0.0090782	0.0079234	-0.0246078	0.0064515	61	13
Test of joint nullity of the effects: p-value = 0.07557589						
Placebo leads						
Placebo_1	-0.0000765	0.0006162	-0.0012843	0.0011313	195	36
Placebo_2	-0.0003498	0.0014791	-0.0032488	0.0025492	124	22
Placebo_3	-0.0019498	0.0028906	-0.0068154	0.0045156	74	12
Placebo_4	-0.0037348	0.0051408	-0.0138105	0.0063409	38	8
Test of joint nullity of the placebos: p-value = 0.71868738						
Event-study effects, countries with at least 1 IXP						
Effect_1	-0.0001739	0.0005928	-0.0013357	0.0009879	54	14
Effect_2	-0.0005918	0.0010377	-0.0025536	0.0015140	50	12
Effect_3	-0.0009557	0.0012898	-0.0034836	0.0015723	45	10
Effect_4	-0.0018085	0.0021442	-0.0060111	0.0023940	42	9
Effect_5	-0.0014426	0.0028982	-0.0071230	0.0042378	42	9
Effect_6	-0.0017528	0.0030337	-0.0076988	0.0041932	42	9
Effect_7	-0.0017801	0.0035891	-0.0088145	0.0052544	39	9
Test of joint nullity of the effects: p-value = 0.08146742						
Placebo leads						
Placebo_1	-0.0010987	0.0013780	-0.0016021	0.0037994	28	11
Placebo_2	-0.0003022	0.0009778	-0.0022187	0.0016143	18	6
Placebo_3	-0.0014389	0.0013947	-0.0041725	0.0012948	10	3
Placebo_4	-0.0017671	0.0020874	-0.0032341	0.0055882	4	1
Test of joint nullity of the placebos: p-value = 0.12160442						

A.1.7 Economic cost of disruptions in low connectivity settings

Table A.1.7.1 Dynamic effects and relative costs (net of spillovers) of cable disruptions on GDP per capita (log), under low connectivity settings.

Effect	Cost (USD pc)	Estimate	SE	LB CI	UB CI	N	Switchers
			Low connectedness: Cable disruptions				
Effect 1	-86.21	-0.0178554	0.0083093	-0.0341413	-0.0015695	227	41
Effect 2	-117.34	-0.0243052	0.0131106	-0.0500015	0.0013911	182	31
Effect 3	-229.60	-0.0475558	0.0182410	-0.0833074	-0.0118041	130	21
Effect 4	-314.08	-0.0650551	0.0235643	-0.1112402	-0.0188700	108	20
Effect 5	-505.17	-0.1046329	0.0432699	-0.1894404	-0.0198254	92	16
Effect 6	-498.76	-0.1033071	0.0446246	-0.1907697	-0.0158445	80	15
Effect 7	-513.48	-0.1063543	0.0497341	-0.2038314	-0.0088772	66	15
			Sample average GDP per capita: 4827.979 USD				
			Low connectedness: Repair days				
Effect 1	-7.10	-0.0014723	0.0007624	-0.0029666	0.0000221	219	39
Effect 2	-6.91	-0.0014322	0.0012359	-0.0038545	0.0009901	175	29
Effect 3	-19.62	-0.0040653	0.0021174	-0.0082153	0.0000847	125	20
Effect 4	-29.30	-0.0060727	0.0028406	-0.0116402	-0.0005053	106	19
Effect 5	-45.38	-0.0094042	0.0047874	-0.0187873	-0.0000211	91	15
Effect 6	-53.39	-0.0110628	0.0057208	-0.0222754	0.0001498	84	15
Effect 7	-50.70	-0.0105054	0.0056461	-0.0215715	0.0005608	70	15
			Sample average GDP per capita: 4825.691 USD				
			No IXP: Cable disruptions				
Effect 1	-108.50	-0.0189173	0.0091647	-0.0368797	-0.0009549	202	39
Effect 2	-109.63	-0.0191145	0.0155196	-0.0495324	0.0113034	153	28
Effect 3	-395.19	-0.0689046	0.0333393	-0.1342484	-0.0035607	105	16
Effect 4	-536.35	-0.0935163	0.0387908	-0.1695448	-0.0174877	93	16
Effect 5	-1052.01	-0.1834262	0.0789860	-0.3382359	-0.0286165	82	13
Effect 6	-854.71	-0.1490254	0.0661469	-0.2786709	-0.0193798	74	13
Effect 7	-891.52	-0.1554429	0.0791558	-0.3105854	-0.0003003	59	12
			Sample average GDP per capita: 5735.356 USD				
			No IXP: Repair days				
Effect 1	-11.18	-0.0016748	0.0008356	-0.0033125	-0.0000370	197	37
Effect 2	-6.60	-0.0009885	0.0014740	-0.0038776	0.0019005	148	26
Effect 3	-27.68	-0.0041464	0.0032831	-0.0105811	0.0022883	107	17
Effect 4	-38.22	-0.0057256	0.0038817	-0.0133337	0.0018824	95	17
Effect 5	-66.05	-0.0098958	0.0070332	-0.0236807	0.0038891	85	14
Effect 6	-73.76	-0.0110500	0.0082536	-0.0272268	0.0051269	77	14
Effect 7	-60.60	-0.0090782	0.0079234	-0.0246078	0.0064515	61	13
			Sample average GDP per capita: 6674.825 USD				

Table A.1.7.2 List of low-connectedness countries – criteria: # connected partners < 10.

ISO	Country	Income group (2008)	Region
AGO	Angola	Lower middle income	Sub-Saharan Africa
ARM	Armenia	Lower middle income	Europe & Central Asia
BDI	Burundi	Low income	Sub-Saharan Africa
BFA	Burkina Faso	Low income	Sub-Saharan Africa
BGR	Bulgaria	Upper middle income	Europe & Central Asia
BWA	Botswana	Upper middle income	Sub-Saharan Africa
CIV	Côte d'Ivoire	Lower middle income	Sub-Saharan Africa
CMR	Cameroon	Lower middle income	Sub-Saharan Africa
COG	Congo, Rep.	Lower middle income	Sub-Saharan Africa
COM	Comoros	Low income	Sub-Saharan Africa
CPV	Cabo Verde	Lower middle income	Sub-Saharan Africa
GAB	Gabon	Upper middle income	Sub-Saharan Africa
GEO	Georgia	Lower middle income	Europe & Central Asia
GHA	Ghana	Low income	Sub-Saharan Africa
GIN	Guinea	Low income	Sub-Saharan Africa
GMB	Gambia, The	Low income	Sub-Saharan Africa
GUY	Guyana	Lower middle income	Latin America & Caribbean
IRQ	Iraq	Upper middle income	Middle East & North Africa
KEN	Kenya	Low income	Sub-Saharan Africa
KHM	Cambodia	Low income	East Asia & Pacific
LBR	Liberia	Low income	Sub-Saharan Africa
MDG	Madagascar	Low income	Sub-Saharan Africa
MDV	Maldives	Lower middle income	South Asia
MLI	Mali	Low income	Sub-Saharan Africa
MOZ	Mozambique	Low income	Sub-Saharan Africa
MRT	Mauritania	Low income	Sub-Saharan Africa
MWI	Malawi	Low income	Sub-Saharan Africa
NAM	Namibia	Upper middle income	Sub-Saharan Africa
PNG	Papua New Guinea	Lower middle income	East Asia & Pacific
RWA	Rwanda	Low income	Sub-Saharan Africa
SDN	Sudan	Lower middle income	Sub-Saharan Africa
SLE	Sierra Leone	Low income	Sub-Saharan Africa
SOM	Somalia	Low income	Sub-Saharan Africa
SUR	Suriname	Upper middle income	Latin America & Caribbean
SWZ	Eswatini (Swaziland)	Lower middle income	Sub-Saharan Africa
SYC	Seychelles	High income	Sub-Saharan Africa
TON	Tonga	Upper middle income	East Asia & Pacific
TZA	Tanzania	Low income	Sub-Saharan Africa
UGA	Uganda	Low income	Sub-Saharan Africa
VUT	Vanuatu	Lower middle income	East Asia & Pacific
ZWE	Zimbabwe	Low income	Sub-Saharan Africa

Table A.1.7.3 List of no-IXP countries – criteria: no IXP.

ISO	Country	Income group (2008)	Region
AGO	Angola	Lower middle income	Sub-Saharan Africa
ARM	Armenia	Lower middle income	Europe & Central Asia
BDI	Burundi	Low income	Sub-Saharan Africa
BFA	Burkina Faso	Low income	Sub-Saharan Africa
BGR	Bulgaria	Upper middle income	Europe & Central Asia
BWA	Botswana	Upper middle income	Sub-Saharan Africa
CIV	Côte d'Ivoire	Lower middle income	Sub-Saharan Africa
CMR	Cameroon	Lower middle income	Sub-Saharan Africa
COG	Congo, Rep.	Lower middle income	Sub-Saharan Africa
COM	Comoros	Low income	Sub-Saharan Africa
CPV	Cabo Verde	Lower middle income	Sub-Saharan Africa
GAB	Gabon	Upper middle income	Sub-Saharan Africa
GEO	Georgia	Lower middle income	Europe & Central Asia
GHA	Ghana	Low income	Sub-Saharan Africa
GIN	Guinea	Low income	Sub-Saharan Africa
GMB	Gambia, The	Low income	Sub-Saharan Africa
GUY	Guyana	Lower middle income	Latin America & Caribbean
IRQ	Iraq	Upper middle income	Middle East & North Africa
KEN	Kenya	Low income	Sub-Saharan Africa
KHM	Cambodia	Low income	East Asia & Pacific
LBR	Liberia	Low income	Sub-Saharan Africa
MDG	Madagascar	Low income	Sub-Saharan Africa
MDV	Maldives	Lower middle income	South Asia
MLI	Mali	Low income	Sub-Saharan Africa
MOZ	Mozambique	Low income	Sub-Saharan Africa
MRT	Mauritania	Low income	Sub-Saharan Africa
MWI	Malawi	Low income	Sub-Saharan Africa
NAM	Namibia	Upper middle income	Sub-Saharan Africa
PNG	Papua New Guinea	Lower middle income	East Asia & Pacific
RWA	Rwanda	Low income	Sub-Saharan Africa
SDN	Sudan	Lower middle income	Sub-Saharan Africa
SLE	Sierra Leone	Low income	Sub-Saharan Africa
SOM	Somalia	Low income	Sub-Saharan Africa
SUR	Suriname	Upper middle income	Latin America & Caribbean
SWZ	Eswatini (Swaziland)	Lower middle income	Sub-Saharan Africa
SYC	Seychelles	High income	Sub-Saharan Africa
TON	Tonga	Upper middle income	East Asia & Pacific
TZA	Tanzania	Low income	Sub-Saharan Africa
UGA	Uganda	Low income	Sub-Saharan Africa
VUT	Vanuatu	Lower middle income	East Asia & Pacific
ZWE	Zimbabwe	Low income	Sub-Saharan Africa

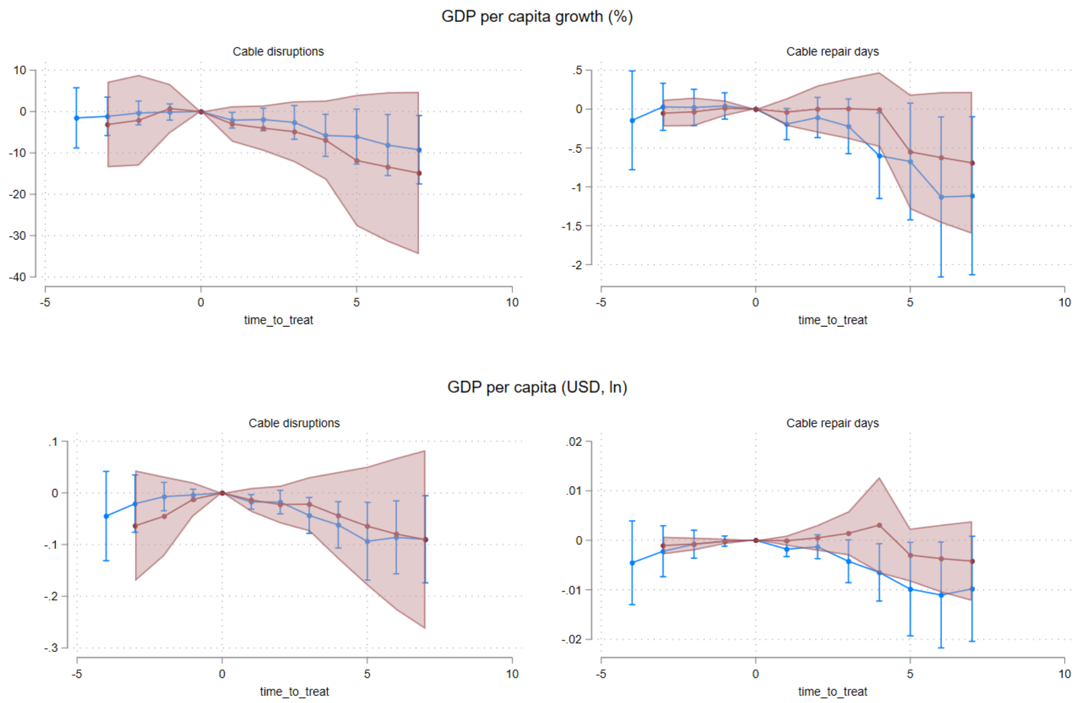

Fig. A.1.7.1 Other exposure factor: Internet penetration

A.1.8 Additional estimations

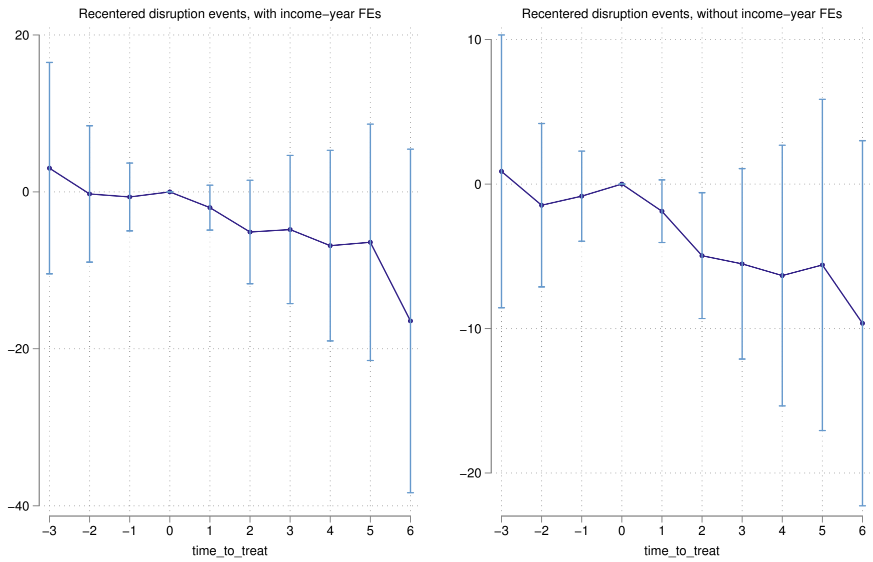

Fig. A.1.8.1 Cable disruptions and GDP per capita growth (%) – Recentering the treatment following Borusyak and Hull (2023).

Notes: Event-study coefficients for GDP per capita growth after recentering the treatment variable by subtracting each country's expected disruption count under a uniform within-country timing assumption: $\tilde{D}_{it} = D_{it} - \bar{m}_i/T_i$, where $\bar{m}_i$ is the country's total disruptions over the sample and T_i its number of observed periods. Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and region-by-year fixed effects, with standard errors clustered at the country level. Left panel includes income-group-by-year fixed effects (48 countries, 492 obs., 25 switchers); right panel excludes them (53 countries, 559 obs., 31 switchers).

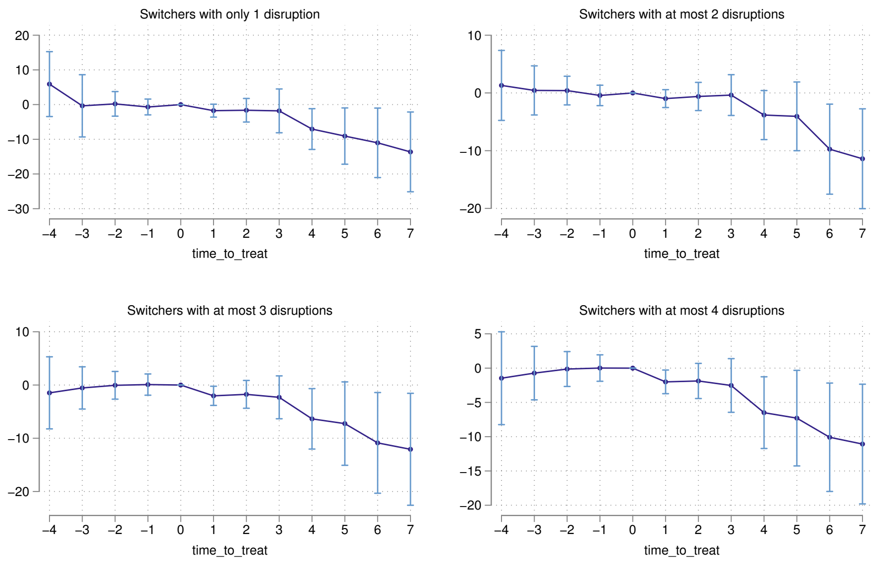

Fig. A.1.8.2 Recurrence of cable disruptions and GDP per cap. growth (%)

Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

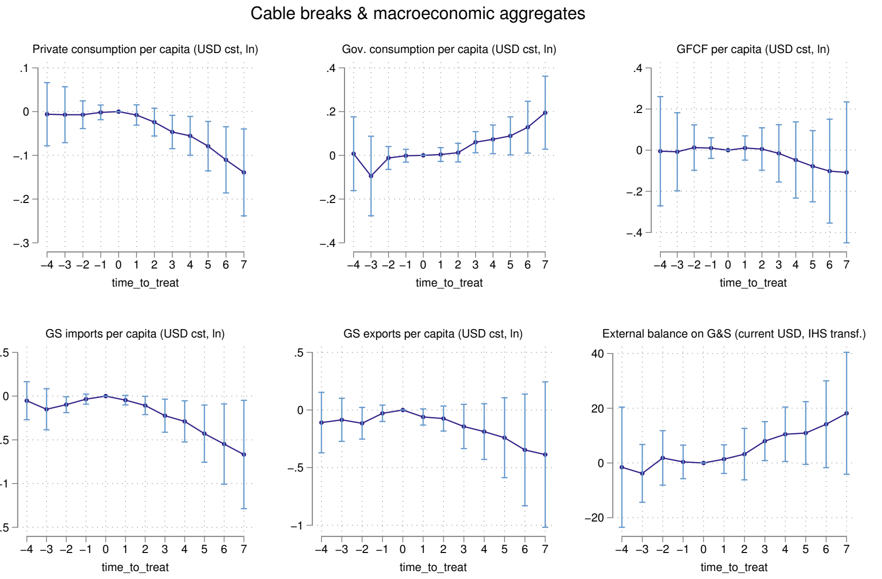

Fig. A.1.8.3 Macroeconomic adjustments following cable breaks.

Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

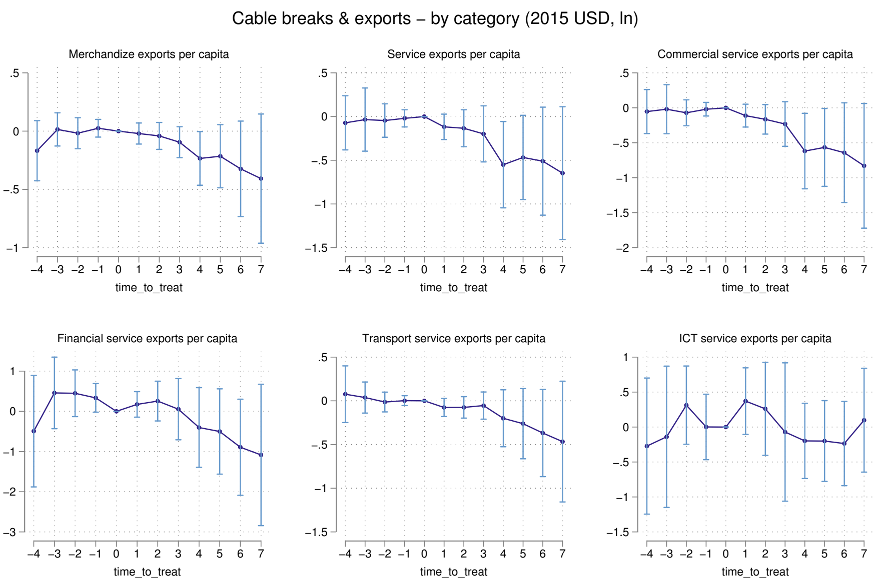

Fig. A.1.8.4 Cable breaks and exports (USD, ln), by category.

Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and $region \times year$ and $income - group \times year$ fixed effects, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

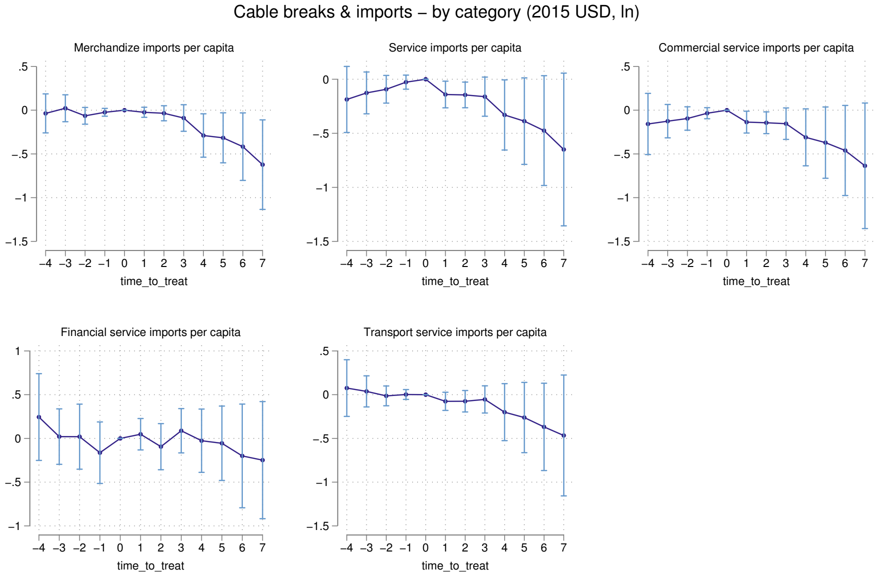

Fig. A.1.8.5 Cable breaks and imports (USD, ln), by category.

Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 7 corresponds to a period of six years after the cable failure occurrence.

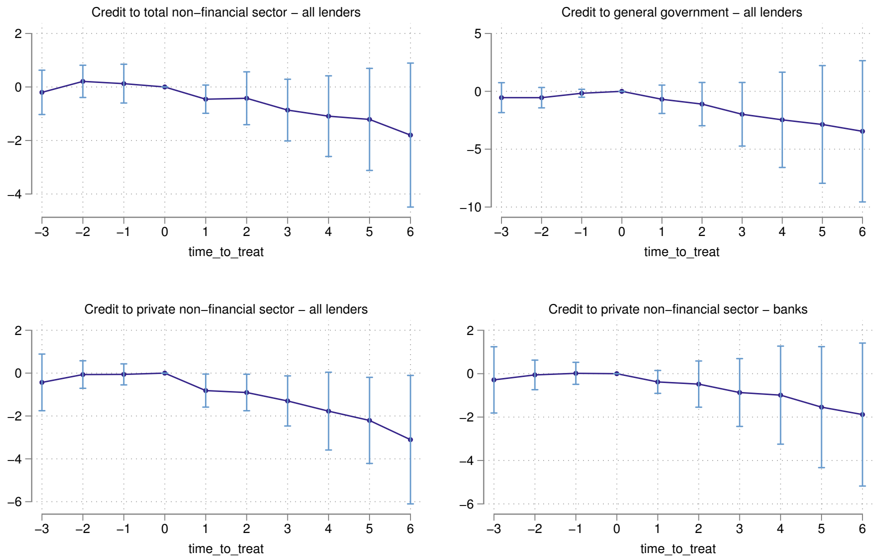

Fig. A.1.8.6 Cable disruptions and credit to non-financial domestic agents (USD, Z-scores).

Data from the Bank of International Settlements (BIS). Variables are winsorized at 90% and standardized afterwards. Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 6 corresponds to a period of five years after the cable failure occurrence. The estimation sample includes 27 high-income and emerging economies (271 observations), with six switchers (76 obs.): Australia, France, United Kingdom, Indonesia, Italy, and Turkey.

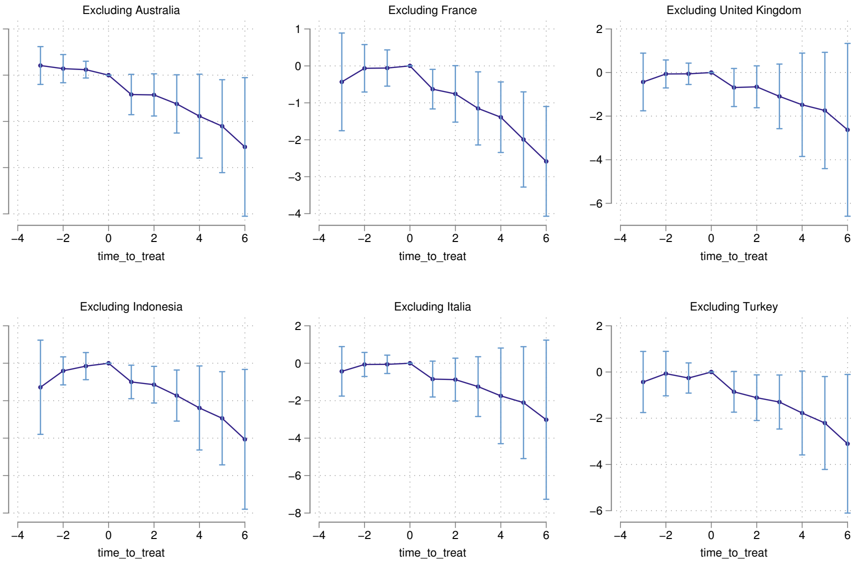

Fig. A.1.8.7 Cable disruptions and credit to non-financial domestic agents (USD, Z-scores), sequentially excluding switchers.

Data drawn from the Bank of International Settlements (BIS). Variables are winsorized at 90% and standardized afterwards. Markers show point estimates; bars denote 95% confidence intervals. Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 6 corresponds to a period of five years after the cable failure occurrence.

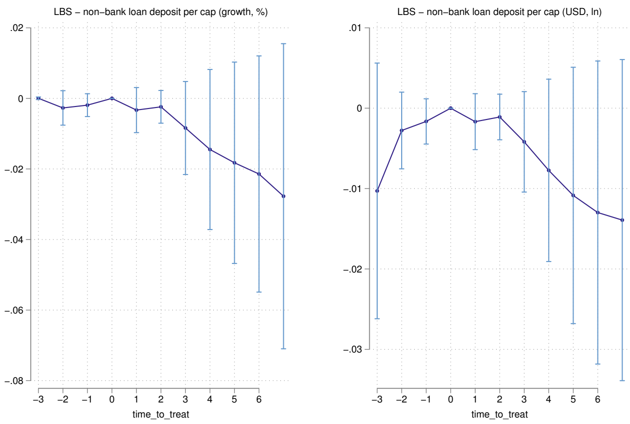

Fig. A.1.8.8 Non-bank loan deposits per capita (USD, ln) - Location Banking Statistics.

Markers show point estimates; bars denote 90% confidence intervals. Data drawn from the Locational Banking Statistics (LBS) from the Bank of International Settlements (BIS). Specifications include country fixed effects, year fixed effects, linear country trends, and nonparametric region and income-group trends, with standard errors clustered at the country level. Year 6 corresponds to a period of five years after the cable failure occurrence. The estimation sample includes 137 countries (1,781 observations), including 50 switchers (650 obs.). High-income and middle-income economies respectively represent 33.6% and 54% of the estimation sample.

A.2 Formal framework for identification under regional spillovers

A.2.1 Potential outcomes with partial (regional) interference

Let S_{rt} denote a measure of *regional exposure* in region r at time t (e.g., the number of disruptions affecting other countries in region r), and write $r(i)$ for country i's region. Under partial interference at the regional level, potential outcomes may depend on both own exposure and regional exposure, $Y_{it}(D_{it}, S_{r(i)t})$, hypothesizing outcomes are not affected by shocks outside the region once I condition on controls and fixed effects.

This structure maps naturally into three groups in a given year/event-time: (i) treated countries T with $D_{it} > 0$; (ii) *spillover-only* countries S with $D_{it} = 0$ but $S_{r(i)t} > 0$; and (iii) *pure controls* C with $D_{it} = 0$ and $S_{r(i)t} = 0$.

A.2.2 Direct, spillover, and total (ITT) effects

With interference, the "direct effect" of a disruption is interpreted as the effect of increasing own exposure while holding fixed the regional exposure faced by both treated and untreated units. In this setting, this corresponds to the contrast

$$\text{Direct effect, net of spillovers}: \quad T - S \;\equiv\; \mathbb{E}\big[\,Y_{it}(D_{it} = 1, S_{r(i)t}) - Y_{it}(D_{it} = 0, S_{r(i)t})\,\big]\,,$$

i.e., treated vs. untreated *within the same exposed regional environment*. The spillover effect is defined as the effect of being untreated but located in an exposed region:

$$\text{Spillover on non-treated}: \quad S - C \;\equiv\; \mathbb{E}\big[\,Y_{it}(0, S_{r(i)t} > 0) - Y_{it}(0, S_{r(i)t} = 0)\,\big]\,.$$

Finally, the total effect of a disruption on treated countries relative to non-exposed controls, referred to as the *Intention-to-Treat* (ITT) under interference, is

$$\text{ITT / total effect}: \quad T - C \;\equiv\; \mathbb{E}\big[\,Y_{it}(1, S_{r(i)t} > 0) - Y_{it}(0, S_{r(i)t} = 0)\,\big]\,.$$

These satisfy the accounting identity:

$$T - C \;=\; (T - S) + (S - C). \tag{2}$$

In other words, the total effect on treated units relative to a pure control decomposes into a direct effect net of spillovers plus spillovers on non-treated units. In the empirical implementation, I construct an *implied ITT* by combining estimates of $(T - S)$ and $(S - C)$.

A.2.3 Mapping to empirical specifications and identification assumptions

The baseline event-study with region-by-year fixed effects, $\delta_{r(i),t}$, identifies $(T - S)$ by comparing treated and untreated countries *within the same region-year*. Region-by-year fixed effects absorb all shocks common to the region in a given year—such as SMC systems deployment, or region-wide diversion and reallocation forces—so identification comes from within-region-year differences in own exposure D_{it}.

To identify spillovers ($S - C$), I estimate a separate event-study on the non-treated sample (restricting to $D_{it} = 0$) in which treatment is a measure of regional exposure, that is, the number of disruption episodes in the region.[43] This design compares non-treated countries in exposed regions to non-treated countries in non-exposed regions, thereby capturing spillovers on untreated units.

Finally, I obtain the implied ITT effect ($T - C$) by combining the two components according to Equation (2). Because both components may be statistically dependent, I compute confidence intervals for the implied ITT using a joint country-cluster bootstrap: in each replication I resample countries, re-estimate the direct and spillover specifications under the main design, compute the average effect over $[t{+}3; t{+}6]$, and then form the total effect for that replication.

This decomposition is informative under two maintained assumptions. First, interference is primarily regional (partial interference), so that S_{rt} is a sufficient summary of exposure to others' disruptions once I condition on fixed effects and controls. Second, conditional parallel trends hold for the relevant comparisons: treated and untreated countries within region-years (for ($T - S$)), and non-treated countries in exposed vs. non-exposed regions (for ($S - C$)). Under these conditions, this framework makes it possible to interpret baseline estimates as direct effects net of spillovers and to recover an implied total effect relative to non-exposed controls.

Table A.2.3.1 reports point estimates and 95% bootstrapped percentile intervals of the implied ITT obtained by combining ($T{-}S$) and ($S{-}C$) via a joint country-cluster bootstrap, averaged over horizons $k \in \{4, \ldots, 7\}$. Two peer-exposure measures are used: a *breadth* measure (number of disrupted peers in the region-year) and a *frequency* measure (number of disruption episodes). The two measures paint a consistent picture but emphasize different features of regional interference. The breadth measure delivers more precise estimates of spillovers and implies a total effect of about -7 percentage points (pp) over $[t{+}3; t{+}6]$ (Panel A). The frequency measure yields substantially larger spillovers (Panel B), consistent with strong diversion when disruptions are recurrent, but the implied total effect is estimated less precisely and centers around -5 pp. Taken together, these estimates align in sign and order of magnitude with the direct $T{-}C$ estimate reported in Figure 4.

A.3 Other information

A.3.1 Internet disruption database: coding protocol

Sources.

The database is built from systematic monitoring of connectivity disruption reports published by *SubTel Forum*, the submarine cable industry's primary technical platform, which documents national-level disruptions caused by cable infrastructure failures in real time. The *SubTel Forum* cable faults and maintenance desk is complemented by two secondary sources: the *Internet Disruption Report* (internetdisruption.report), a periodic compilation of global connectivity incidents cross-referenced against operator announcements; and Akamai's *State of the Internet Connectivity* reports for earlier years. Each event is cross-checked against targeted web searches combining the country name, the cable system name, and the approximate date. The database covers 2008–2020; the estimation sample is restricted to 2008–2020.

[43] I also use the regional number of disrupted economies as complementary approach to estimating spillover effects. However, since multiple countries can be affected by only one disruption in a region, the resulting estimates cannot be used to measure the implied ITT effect.

Table A.2.3.1 Average direct, spillover, and implied intention-to-treat effects at horizon $[t+3; t+6]$, with bootstrapped confidence intervals.

Effects	Valid reps	Point est.	Bootstrapped 95% CI
Direct effect (TS): $T-S$	415	−8.937	[−22.073; −2.436]
Panel A: Number of regional disrupted peers			
Spillovers (SC): $S-C$	415	1.664	[0.184; 3.319]
Implied ITT (TC): $\text{TS}+\text{SC}$	415	−7.273	[−20.008; −0.616]
Panel B: Number of regional disruption episodes			
Spillovers (SC): $S-C$	415	3.611	[0.3928; 7.196]
Implied ITT (TC): $\text{TS}+\text{SC}$	415	−5.326	[−18.606; 2.094]

Notes: All specifications include country fixed effects, year fixed effects, linear country trends; but exclude income-group-by-year fixed effects. TS corresponds to the direct effect estimated with region-by-year fixed effects (within-region identification). SC corresponds to the spillover effect estimated on the non-treated sample (comparing non-treated units in exposed vs. non-exposed regions). TC is constructed as TC = TS + SC. Following standard definitions under interference (e.g. Özler (2018)), the ITT (treated vs. pure control) decomposes as $(T-C) = (T-S) + (S-C)$. Reported statistics come from 415 valid country-cluster bootstrap replications in each panel; the 95% confidence interval is the percentile bootstrap interval (2.5th and 97.5th percentiles). TS, SC, and TC are computed as the average of event-study coefficients at horizons [t+3; t+6].

Unit of observation.

The raw database records connectivity disruption events at the country–event level. A single physical cable fault can impair connectivity in multiple countries simultaneously: each affected country is recorded as a separate observation, reflecting the principle that effects are measured from the perspective of what each country experiences, not from proximity to the physical break. For instance, the December 2008 failure of the SEA-ME-WE 4 and FLAG systems, caused by a vessel anchor in the Mediterranean, generated 14 country-level disruption events across Asia, the Middle East, and Southern Europe.

Attribution criterion.

A country is coded as disrupted only when operators or contemporary sources explicitly report a measurable loss of international connectivity—degraded throughput, partial or full outage, or confirmed rerouting with service impact—attributable to a cable infrastructure failure. Countries that are topologically connected to the faulted cable but for which traffic is successfully rerouted without reported degradation are coded as not treated. This *material-impact* criterion ensures that treatment captures experienced connectivity loss rather than physical proximity to the fault.

Event taxonomy.

Each raw event is assigned one of the following categories on the basis of source descriptions. *Cable breaks* are disruptions explicitly linked to a physical cut or break requiring dispatch of a repair vessel; these constitute the primary treatment events. *Cable outages* are service-affecting faults without confirmed physical damage—repeater failures, power-feed faults, branching-unit malfunctions—and are retained as secondary treatment events. *Network disruptions* cover connectivity losses attributable to routing issues, DNS problems, or other technical failures not involving cable infrastructure damage. *Other-cause* events include government-ordered shutdowns, sabotage of terrestrial or submarine fiber, power outages, natural disasters (cyclones, earthquakes, floods), cyber attacks, and scheduled maintenance operations.

Treatment variable construction.

The estimation sample retains only cable breaks and cable outages as treatment-generating events, and constructs two country-year variables: (i) *cable disruptions*: the annual count of SMC-induced connectivity losses; and (ii) *repair days*: the annual sum of connectivity-loss days associated with these events. Government-ordered shutdowns, sabotage, power failures, natural-disaster-caused disruptions, routing issues, and events of unknown cause are coded separately and excluded from the treatment variable. As robustness checks, I drop events associated with suspected or confirmed sabotage and events coinciding with natural disasters that could independently affect economic outcomes (Section 5).

A.3.2 Domestic credit variables

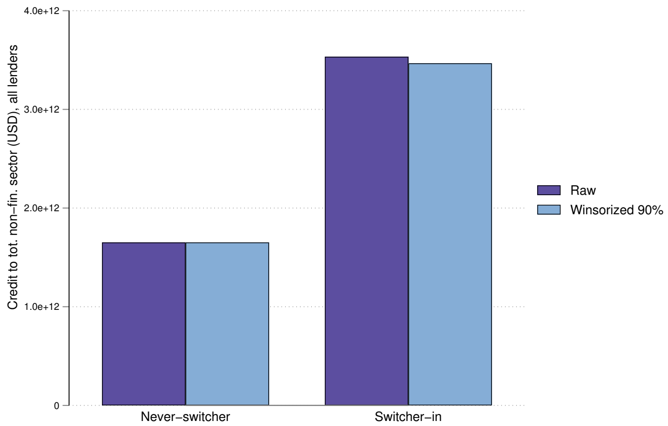

Fig. A.3.2.1 Domestic credit to non-financial domestic actors (USD), switchers versus never switchers. The sample includes 27 high-income and emerging economies (271 observations), with six switchers (76 obs.): Australia, France, United Kingdom, Indonesia, Italy, and Turkey. The credit variable is winsorized at 90% to ensure that results are not driven by outliers.

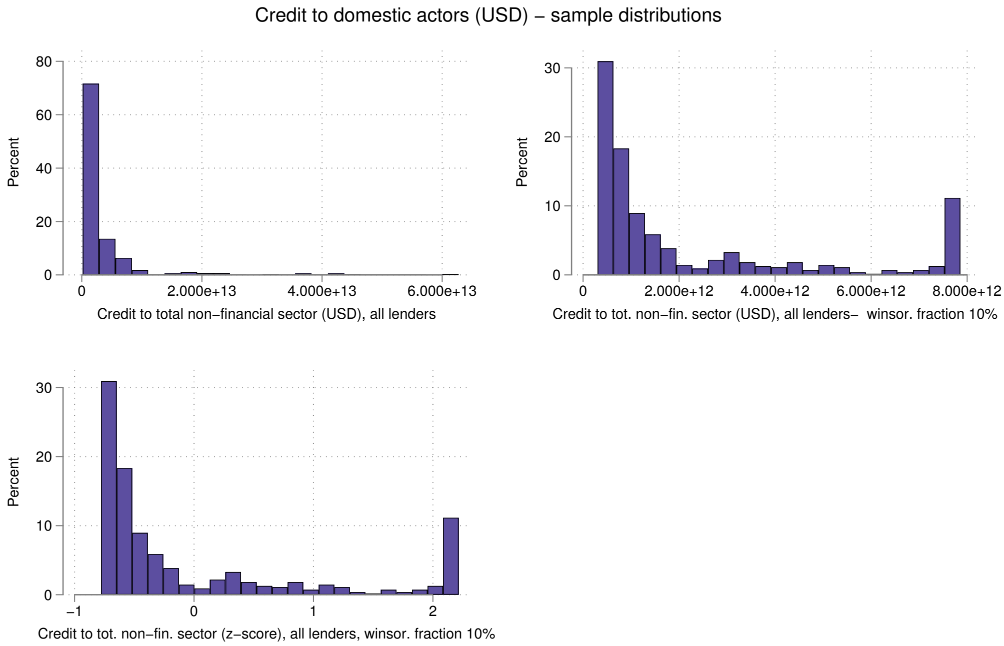

Fig. A.3.2.2 Domestic credit to non-financial domestic actors (USD), variable distributions.

A.3.3 SMC maintenance areas

Fig. A.3.3.1 SMC maintenance areas.
Source: Global Marine Systems Ltd..