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Connecting to Trade: Fixed Broadband, Regulation, and Digitally Deliverable Services in Africa

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Abstract

This paper examines the conditions under which digital infrastructure and telecommunications regulation are associated with trade in digitally deliverable services (DDS), focusing on Africa, where fixed-broadband adoption remains low. Fixed broadband is more strongly associated with DDS trade than mobile broadband, mainly on the export side. Telecommunications regulation is associated with more services trade globally, but the relationship is weaker and, in some specifications, negative in Africa. It tends to be positive only where institutional capacity, reliable electricity, education and broadband penetration are sufficiently high, conditions that are less often met in Africa. The paper then asks why fixed-broadband adoption remains low. Mobile adoption responds to price; fixed adoption shows no comparable response, and none that varies with income. Where networks are incomplete, observed fixed-broadband uptake therefore appears to be limited by network availability more than by price. For African economies seeking to expand digital services exports, the results point to the need for fixed infrastructure, regulation that can be implemented, and complementary investment in electricity and skills.

Keywords: digital services trade; digital divide; telecommunications regulation; complementary factors; Africa

JEL classification: F14, L96, O33, O55, L51

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1 Introduction*

Digitally delivered services account for more than half of global services exports and offer African economies an opportunity to expand their participation in international trade. African exports of these services grew faster than goods exports between 2005 and 2022, with growth accelerating to 13 per cent in 2024. Yet Africa still accounts for less than one per cent of global exports, with Ghana, Morocco and South Africa representing more than half of the continent's exports in 2022 (World Bank & WTO, 2023, 2025). The potential for further growth is considerable: WTO simulations suggest that wider adoption of digital technologies could increase African exports of digitally delivered services by approximately US$ 74 billion between 2023 and 2040 (World Bank & WTO, 2023). Realising this potential, however, depends partly on the availability and quality of digital connectivity and on the regulatory conditions governing its provision.

Africa's experience with telecommunications highlights an important gap in this regard. According to ITU data, mobile subscriptions in Africa increased from 1.7 per 100 inhabitants in 2000 to 91.7 in 2025, approaching the global average. Active mobile broadband subscriptions reached 55.5 per 100 inhabitants, although this remained approximately half the global average. This expansion was facilitated by telecommunications reforms, trade liberalisation, independent regulators and pent-up demand, as well as the absence of legacy fixed-line infrastructure (Moshi & Mwakatumbula, 2017). Progress in fixed broadband, by contrast, has been much more limited: African penetration remains approximately 6 per cent of the global average. This gap matters for digital services trade because fixed broadband provides the high-capacity and reliable connections required by many digitally intensive business activities. It also supports mobile networks through the fibre-optic backhaul needed for efficient 4G and 5G connectivity. Thus, the expansion of mobile access does not remove the need to develop fixed-network infrastructure.

These connectivity challenges have become increasingly important in Africa's digital trade agenda. The African Union adopted the AfCFTA Protocol on Digital Trade in February 2024, establishing a framework for cooperation on market access, trade facilitation, data governance, trust and inclusion (African Union, 2024). Complementary initiatives include the World Bank's Digital Economy for Africa programme and the joint World Bank–WTO Digital Trade for Africa project (World Bank & WTO, 2023, 2025). At the multilateral level, 66 WTO members adopted interim arrangements for the Agreement on Electronic Commerce in March 2026, with limited African participation so far (World Trade Organization, 2026). Telecommunications regulation, which is the focus of this paper, also has established multilateral benchmarks in the WTO Telecommunications Reference Paper, covering competitive safeguards, interconnection, licensing and regulatory independence, and in the GATS Annex on Telecommunications, which guarantees access to public networks (World Trade Organization, 1996, 1994). African economies account for 12 of the 106 members that have subscribed to the Reference Paper (World Bank & WTO, 2023). Together, these initiatives reflect an agenda that combines regulatory cooperation with investment in digital infrastructure. An important question is whether, and under what conditions, these efforts translate into greater trade in digitally deliverable services.

This paper examines the relationship between connectivity, telecommunications regulation and

[1]The authors are grateful to Roberta Allport, Joël Cariolle, Antonia Carzaniga, Martina Ferracane, Mena Hassan, Youlia Lozanova, Stela Rubinova, as well as participants of the Conference on Empirical Investigations in Services Trade, the Geneva Trade and Development Workshop and the IMF-World Bank-WTO Trade Workshop for their comments on earlier drafts of the paper.

bilateral trade in digitally deliverable services (DDS).[1] We focus on the conditions that shape the effectiveness of connectivity and regulatory frameworks in Africa. Our analysis proceeds in three steps. First, we document Africa's distinctive connectivity trajectory, characterised by the rapid expansion of mobile telephony alongside persistently low fixed-broadband penetration. Second, using structural gravity models, we examine the relationship between fixed and mobile broadband, telecommunications regulation and DDS trade. We find that fixed broadband is more strongly associated with DDS trade than mobile broadband, while the positive relationship between telecommunications regulation and trade observed globally does not extend to Africa. We investigate three possible explanations for this divergence: limited implementation capacity, the absence of complementary infrastructure and institutional conditions, and the way regulatory scope is measured. The evidence points primarily to the first two. Third, we investigate the determinants of fixed and mobile broadband adoption. The results suggest that fixed-broadband adoption is more closely associated with network availability than with prices, while regulatory upgrading is associated with higher fixed-broadband prices and prices decline as subscriber density increases. Together, these findings highlight the importance of infrastructure and institutional conditions in translating digital policy reforms into trade gains.

Related Literature

This paper contributes to three interconnected literatures on digital connectivity, services trade, and regulation in developing economies.

Digital Connectivity and Economic Outcomes: A growing body of literature documents the economic and social consequences of improved internet connectivity in developing economies, highlighting its role in reducing trade costs, expanding market access, and facilitating firms' integration into domestic and international markets (Hjort & Tian, 2025). A prominent contribution is Hjort & Poulsen (2019), who exploit the arrival of submarine internet cables in Africa between 2009 and 2012 and show that improved connectivity increased firm entry and employment, with particularly pronounced effects on skilled employment. Similarly, Cariolle & da Piedade (2023) find that greater internet access increases export complexity across 60 developing economies, suggesting that connectivity can affect not only the volume of trade but also the sophistication of exported products. In the financial sector, D'Andrea & Limodio (2024) show that access to high-speed internet accelerates the adoption of real-time gross settlement systems among African banks and expands the supply of credit. More broadly, Herman & Oliver (2023) document a positive relationship between internet connectivity and trade in both goods and services, while showing that greater connectivity can generate substantial welfare gains in some developing economies. At the same time, they highlight a potential divergence effect whereby poorly connected economies risk falling further behind as the digital economy expands.

An emerging strand of this literature examines the distributional consequences of connectivity and emphasizes that its benefits are not uniform across workers and firms. Chiplunkar & Goldberg (2022), for example, find that improved connectivity increases labor force participation, but with heterogeneous effects across gender: men experience larger employment gains, while women increasingly move into agricultural jobs vacated by men who transition to better employment

[1] We follow the *Handbook on Measuring Digital Trade* (IMF-OECD-UNCTAD-WTO, 2023). It defines digitally *delivered* services as international services transactions delivered remotely over computer networks. Because actual delivery is rarely observed, it identifies digitally *deliverable* services from categories of the Extended Balance of Payments Services Classification, and treats the result as an upper bound on delivered trade.

opportunities. At the firm level, Imbruno et al. (2025) show that the gains from improved connectivity are concentrated among more productive exporters, while smaller and less productive firms may be displaced from global markets. Taken together, this literature suggests that digital connectivity can generate substantial gains in productivity, trade, employment, and welfare, but that these gains depend importantly on firms' productive capacity, workers' ability to adjust, and the broader economic environment. These findings also point to the importance of understanding not only whether connectivity expands, but also the conditions under which it translates into broader economic opportunities. Our contribution to this literature is to demonstrate that connectivity's impacts on services trade depend on the type of infrastructure (fixed vs. mobile broadband) and that these benefits require complementary investments, particularly in education and electricity.

Determinants of Connectivity: Despite extensive documentation of connectivity's impacts, its determinants remain under-researched, particularly for Africa. Cariolle (2021) analyses the impact of submarine cable rollouts on internet penetration in Eastern and Southern Africa, finding effects of 3–5 percentage points, with electricity access, geographical constraints, and institutional quality identified as important moderating factors. Buys et al. (2009) find strong effects of competition policy on mobile phone coverage in Africa, while Na et al. (2020); Viard & Economides (2015) highlight content availability as a driver of global internet adoption. Much of this literature, however, relies on data from the early 2000s and has not adequately addressed why similar regulatory reforms yield different outcomes across regions, nor explored the potential endogeneity between services trade and connectivity investment.

We build on this foundation by providing updated empirical evidence using recent data (through 2024 for the trade analysis) and by modeling connectivity supply and demand as a rationed market in which access is constrained by network availability.

Telecommunications Regulation and Trade: A substantial literature examines the effects of regulations in the telecommunications sector. For instance, Wallsten (2001) shows that greater competition, measured by the presence of non-incumbent mobile operators, is associated with higher-quality and lower-cost services, while privatization alone delivers limited gains. Djiofack-Zebaze & Keck (2009) find that regulation and privatization in telecommunications can affect access, but effects vary substantially depending on implementation. More recent research extends the analysis to examine the effect of regulatory quality on services trade. Beverelli et al. (2017) and Nordås (2016) show that regulatory heterogeneity can create barriers to services trade, while Nordås & Rouzet (2014) demonstrate that telecommunications regulatory quality influences services trade performance across a broad range of sectors. Closest to our setting, Bellucci et al. (2025) show that digital connectivity lowers trade costs in both goods and services, and that this effect is substantially amplified by regulation guaranteeing open access to communications infrastructure and free cross-border data flows, with the largest amplification found for digitally deliverable services. The same premise runs through the policy literature on Africa. A joint World Bank–WTO note estimates that raising African mobile broadband to the South African level, and regulation to the best African standard, would lower trade costs in business and professional services by about a quarter (World Bank & WTO, 2023).

Our paper contributes to this literature in two ways. First, we document systematic regional heterogeneity in the effectiveness of telecommunications regulation, revealing weak and in some cases negative associations between the score on the ITU regulatory tracker and services trade in African countries. Second, we investigate potential mechanisms underlying these patterns and

show that regulatory frameworks alone are insufficient to generate digital trade gains. Regulatory capacity, together with complementary investments in education and electricity, plays a critical role in translating reforms into improved connectivity and trade outcomes.

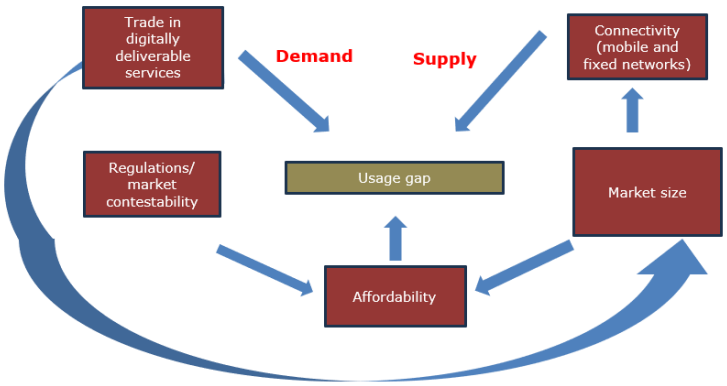
The remainder of the paper proceeds as follows. Section 2 establishes five stylized facts about connectivity patterns in Africa. Section 3 employs structural gravity models to show that fixed broadband has substantially larger effects on digital service trade than mobile connectivity, and documents the Africa paradox in regulatory effectiveness. We test three hypotheses to explain this pattern and find support primarily for implementation gaps and missing complementarity. Section 4 develops and estimates a model of connectivity supply and demand, and finds that fixed-broadband adoption is rationed by network availability rather than limited by price. Section 5 synthesizes the findings and develops policy implications.

2 Data and Stylized Facts

This section documents five stylized facts about digital connectivity in Africa. The evidence is descriptive, based on bivariate scatterplots and fitted lines, and is intended to identify patterns that motivate the econometric analysis in Sections 3 and 4.

Figure 1 summarises the relationships examined in the paper. We distinguish the *supply* of connectivity—the networks that reach households, shaped by regulation, market structure and investment incentives—from its *demand*, which depends on affordability, digital skills and the availability of relevant content. Trade in digitally deliverable services (DDS) is connected to both. Imports expand the range of digital content and services available to users, potentially increasing the value of connectivity, while exports depend on the capacity and reliability of digital networks. Regulation can influence both sides through its effects on investment, competition and pricing. The five facts below describe where African economies differ from other regions within this broader framework.

Figure 1: *Conceptual framework: The virtuous cycle of digital connectivity*



Note: This figure illustrates hypothesized relationships between connectivity infrastructure (supply), services trade and content (demand), and policy variables (regulation, trade openness).

2.1 Data Sources

The analysis combines data on trade, connectivity, regulation and complementary economic conditions. Table 1 summarises the main sources and their coverage.

Table 1: *Data Sources and Coverage*

Dataset	Source	Year Coverage
Broadband Prices	ITU	2008–2025
Broadband Coverage and Subscriptions	ITU	2002–2024
ITU ICT Regulatory Tracker	ITU	2007–2024
Internet speed and latency	Ookla	2019–2025 (mobile)
	Ookla, via Harvard Dataverse	2008–2014; 2019–2025 (fixed)
BaTiS (Dec 2025)	WTO–OECD	2005–2024
ITPD-E (Release 2025)	Larch et al. (2025)	2000–2023

We use two datasets on trade in DDS: the International Trade and Production Database (ITPD-E) (Larch et al., 2025; Borchert et al., 2021), Release 2025, and the WTO–OECD Balanced Trade in Services (BaTiS) database. ITPD-E includes domestic sales alongside international trade, allowing us to identify country-specific determinants of international trade relative to domestic activity, but covers fewer economies. BaTiS includes only cross-border flows but offers broader coverage, particularly of developing economies, although a substantial share of its observations is estimated using various statistical techniques rather than directly reported.

Connectivity indicators, including fixed and mobile broadband subscriptions, network coverage and broadband prices, are obtained from the ITU World Telecommunication/ICT Indicators Database. Regulation is measured by the ITU ICT Regulatory Tracker, a composite index based on 50 indicators across four dimensions: Regulatory Authority, Regulatory Mandate, Regulatory Regime and Competition Framework.

Electricity access and education indicators are drawn from the World Bank's World Development Indicators, while government effectiveness is measured using the Worldwide Governance Indicators. Standard gravity variables come from CEPII's gravity database (Conte et al., 2022). To measure internet performance, we use Ookla's open data platform,[2] which provides quarterly, tile-level observations from 2019 onwards. We aggregate these data to the country-year level and complement them with archived Ookla data from Harvard Dataverse for 2008–2014.[3]

Unless stated otherwise, the figures below pool country-year observations for 2020–2025, distinguish African from non-African economies, and fit separate ordinary least squares (OLS) lines for each group. The comparisons therefore describe differences in the distributions and fitted relationships across the two groups, rather than differences between individual countries. They are descriptive and should not be interpreted as causal relationships.

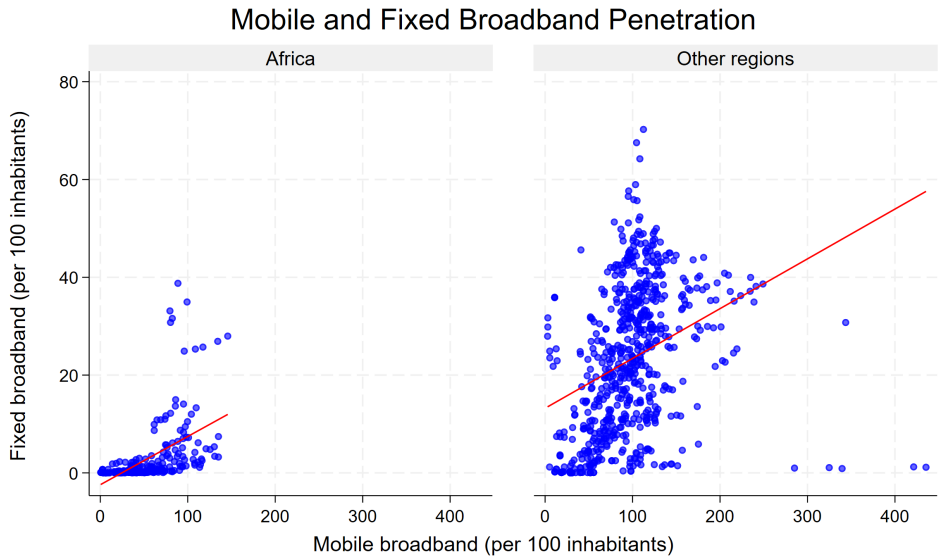
[2] https://github.com/teamookla/ookla-open-data

[3] The historical dataset does not distinguish between fixed and mobile connections. Given the more limited diffusion of mobile broadband during 2008–2014, we interpret these observations as primarily reflecting fixed broadband performance.

Stylized Fact 1: Africa's broadband development remains mobile-first

Mobile and fixed broadband provide different, but complementary, forms of connectivity. Mobile networks offer portability and broad population coverage, supporting communication, social media and mobile commerce. Fixed broadband can provide higher capacity and more reliable connections, which are important for data-intensive business activities such as cloud computing, remote work and enterprise software. The balance between the two therefore matters for the range of activities that digital infrastructure can support.

Figure 2: *Mobile and fixed broadband complementarity: Africa's mobile-first development path*



Note: The figure plots fixed subscriptions to high-speed internet (TCP/IP connection, ≥256 kbit/s) per 100 inhabitants (vertical axis) against mobile-broadband subscriptions (handset-based and USB/dongles) per 100 inhabitants (horizontal axis) for 2020–2025. Left panel: Africa; right panel: other regions. Fitted lines use OLS regression by region. Data source: ITU.

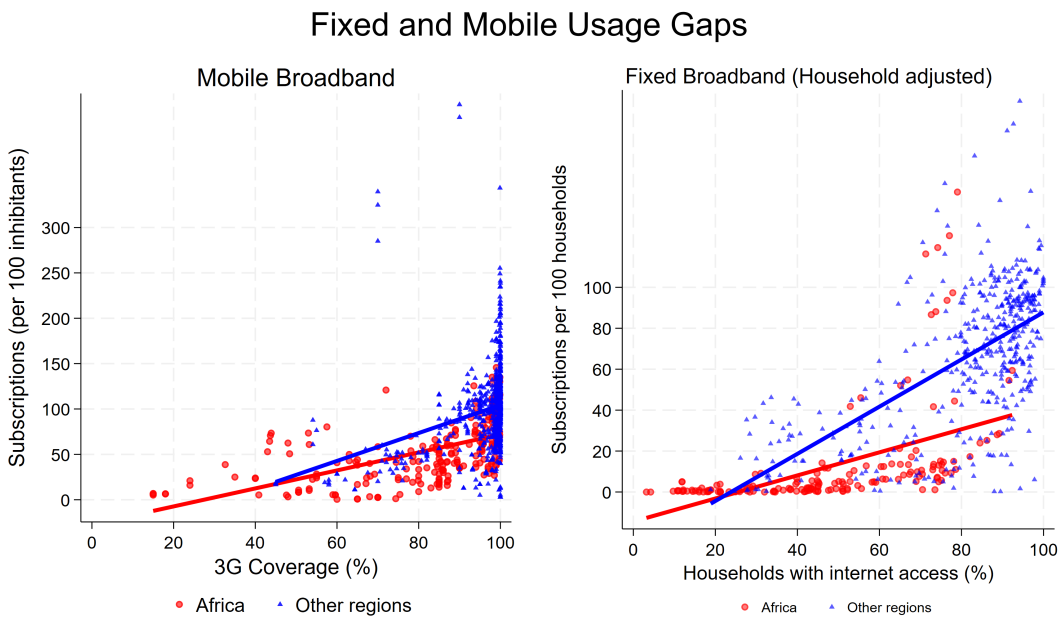
Figure 2 plots fixed against mobile broadband subscriptions per 100 inhabitants. In both African and non-African economies, the fitted relationship is positive, suggesting that the two technologies tend to expand together rather than substitute for one another. However, the levels differ substantially. The fitted line for non-African economies has a vertical intercept of approximately 13 fixed subscriptions per 100 inhabitants, compared with an intercept close to zero for Africa. The African relationship is also considerably flatter: at 80 mobile subscriptions per 100 inhabitants, non-African economies have around 21 fixed subscriptions, compared with approximately five in Africa.

This pattern is consistent with a mobile-first development path. The limited legacy of fixed-line infrastructure and the rapid expansion of mobile networks have shaped the composition of connectivity investment across the continent (Moshi & Mwakatumbula, 2017). Mobile expansion has substantially improved access to communication services, but it has not been accompanied by a comparable expansion of fixed infrastructure. The distinction is relevant for digital services trade: as the gravity analysis in Section 3 shows, fixed broadband has a stronger association with DDS trade than mobile broadband. The challenge is therefore not simply to extend connectivity, but also to broaden the infrastructure base that supports more demanding digital activities.

Stylized Fact 2: The fixed-broadband gap concerns both availability and adoption

Network coverage and actual use are not the same. A network may pass a household without the household taking up a subscription. Distinguishing between *access connectivity* (network availability) and *use connectivity* (actual adoption) helps identify whether limited connectivity reflects insufficient infrastructure, barriers to adoption, or both.

Figure 3: *Africa's usage gap more pronounced for fixed broadband*



Note: Left panel: mobile-broadband subscriptions per 100 inhabitants against the percentage of the population covered by at least a 3G network. Right panel: fixed-broadband subscriptions per 100 households against the percentage of households with Internet access at home (ITU indicator HH6), 2020–2025. Fixed subscriptions are rescaled from a per-100-inhabitant to a per-100-household basis by multiplying by average household size from the United Nations Database on Household Size and Composition (United Nations, Department of Economic and Social Affairs, Population Division, 2022), with values interpolated between survey years. Fitted lines use OLS regression by region. Data source: ITU.

Figure 3 compares subscriptions with measures of network coverage. Data on the share of households passed by fixed wired networks are sparse for African economies.[4] We therefore proxy fixed-network access using the share of households with internet access at home (ITU indicator HH6). This measure is broader than fixed-network coverage: a household qualifies if Internet access is generally available to its members through either a fixed or mobile connection, including a shared mobile subscription (International Telecommunication Union, 2020). It may consequently overstate fixed-network availability, particularly in economies where mobile connectivity is widespread. The two series are also measured on different bases, so fixed subscriptions are converted to a per-100-household measure using average household size (United Nations, Department of Economic and Social Affairs, Population Division, 2022).

For mobile broadband, subscriptions increase broadly in line with coverage in both groups, with fitted slopes of 0.99 in Africa and 1.53 elsewhere. The relationship is weaker for fixed broadband: the African fitted slope is 0.56, compared with 1.15 in other regions, and the African line lies below

[4]ITU's coverage indicator (i4213cv) reports values for only 18 African economies, almost all confined to 2018–19, and several observations appear implausible.

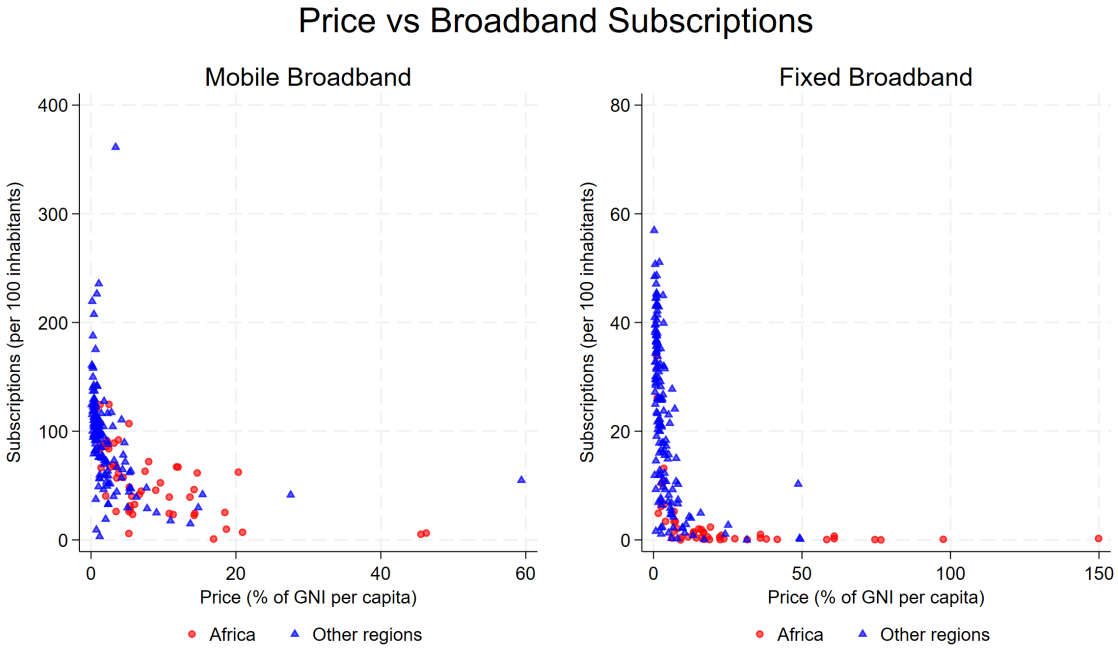
the comparison line throughout the observed range. Thus, increases in household Internet access are associated with a smaller increase in fixed subscriptions in Africa. Complementary evidence points to a substantial usage gap in mobile connectivity as well. At the end of 2021, approximately 84 per cent of people in Sub-Saharan Africa lived in areas with 3G coverage and 54 per cent had some 4G coverage, but only 22 per cent were using mobile Internet (Begazo et al., 2023; World Bank & WTO, 2023).

Taken together, the first two facts point to a two-sided fixed-broadband challenge: network availability remains limited, and the relationship between available access and actual adoption is weaker than elsewhere. The evidence does not allow us to isolate the precise contribution of coverage and take-up, particularly given the limitations of the fixed-network proxy. Nevertheless, it suggests that expanding infrastructure alone may not be sufficient. Policies also need to address the conditions that determine whether households and firms connect to networks that are already available.

Stylized Fact 3: Fixed broadband is expensive, but adoption does not closely track price

Affordability is an obvious candidate explanation for low broadband adoption. Figure 4 plots subscriptions against broadband price baskets, measured as a share of monthly GNI per capita, for mobile and fixed broadband.

Figure 4: *Africa faces higher prices and lower uptake*



Note: The figure plots broadband subscriptions per 100 inhabitants against broadband price baskets as a percentage of monthly GNI per capita for 2020–2025. Left panel: mobile broadband; right panel: fixed broadband. No fitted lines are drawn, and the axis scales differ between panels. Data source: ITU.

For mobile broadband, the descriptive relationship is consistent with affordability constraints. The central 80 per cent of African observations combine prices between 1% and 18% of monthly

GNI per capita with subscription rates between 10 and 99 per 100 inhabitants. Outside Africa, prices are generally lower, typically between 0% and 5% of GNI, while subscription rates are higher, between 40 and 140 per 100 inhabitants. In both groups, the scatterplot shows a negative association between price and adoption.

The pattern is less clear for fixed broadband. African prices are substantially higher, with the central 80 per cent of observations ranging from 2.5% to 48% of monthly GNI per capita, while subscription rates range from zero to eight per 100 inhabitants. Yet within Africa, there is little apparent relationship between price and adoption: even where fixed broadband is relatively affordable, subscriptions rarely exceed five per 100 inhabitants. This does not imply that prices are unimportant, but suggests that affordability alone cannot explain the limited take-up. The World Bank and WTO similarly report that fixed broadband for business use costs approximately seven to eight times the Broadband Commission affordability benchmark in Africa (World Bank & WTO, 2023).

The contrast between mobile and fixed broadband points to different adoption constraints. Price differences are associated with substantial variation in mobile take-up, whereas fixed adoption remains low across a wide range of observed prices. This raises the possibility that fixed-broadband adoption depends more heavily on whether networks are available and sufficiently developed to serve households and firms. Section 4 examines this possibility more formally, distinguishing the role of prices from that of network availability.

Stylized Fact 4: Regulation and fixed-broadband prices are positively associated in Africa

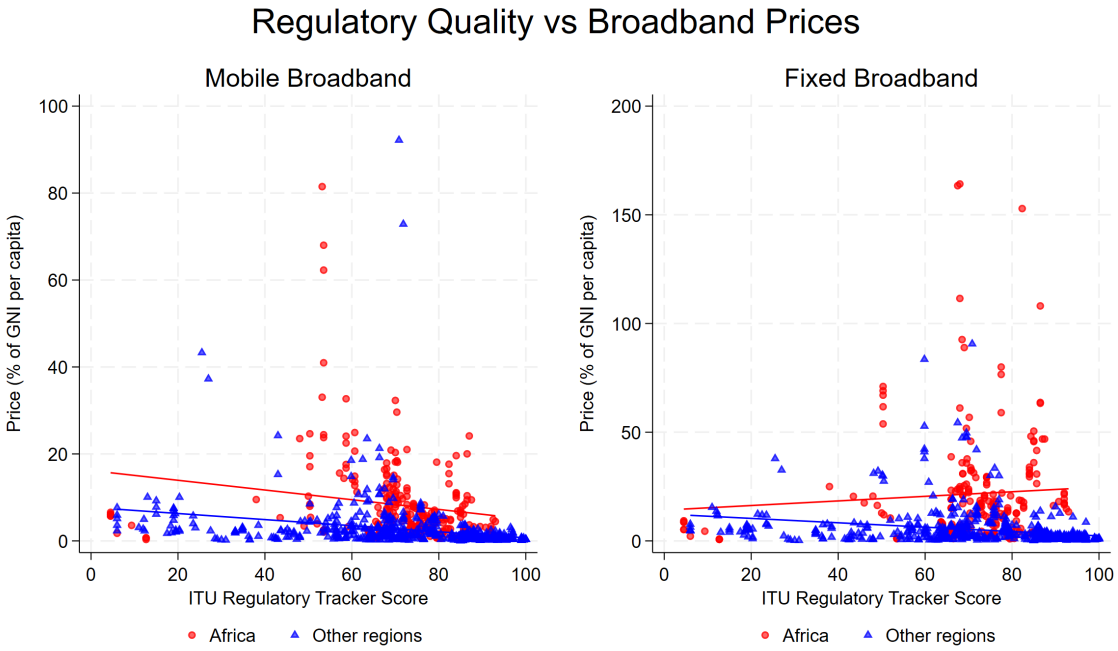
Regulatory improvements are generally expected to strengthen competition and contribute to lower prices. Figure 5 examines whether this relationship is similar across technologies and regions by plotting broadband prices against the ITU ICT Regulatory Tracker.

For mobile broadband, higher regulatory scores are associated with lower prices in both African and non-African economies. The pattern is consistent with the view that stronger regulatory frameworks can support competition and improve market conditions for consumers and operators.

For fixed broadband, the relationship differs across regions. Outside Africa, higher regulatory scores are also associated with lower prices. Within Africa, however, the fitted relationship is positive: economies with higher regulatory scores tend to have more expensive fixed-broadband price baskets. This is not evidence that regulatory improvements cause prices to rise. Rather, it indicates that the relationship between measured regulatory scope and fixed-broadband prices differs from the pattern observed elsewhere and warrants further investigation.

This divergence may reflect differences in market structure, investment conditions and the capacity to implement regulatory provisions. For example, regulatory upgrading may accompany broader sectoral reforms or changes in market structure that also affect prices. The scatterplots cannot distinguish between these explanations or account for other country characteristics that influence both regulation and prices. Nevertheless, the pattern provides a useful descriptive counterpart to the regulatory results in Section 3. Appendix A shows that the positive African association is present across all four components of the ICT Regulatory Tracker, rather than being driven by a single regulatory dimension.

Figure 5: *Regulatory scope and broadband prices: a divergent pattern for fixed broadband in Africa*



Note: The figure plots broadband price baskets (as a percentage of monthly GNI per capita) against the ITU ICT Regulatory Tracker, 2019–2022. Left panel: mobile broadband (2GB plan); right panel: fixed broadband (5GB basket). Fitted lines use OLS regression by region. Data source: ITU. Figure 10 in Appendix A decomposes the Tracker into its four constituent clusters.

Stylized Fact 5: Regulatory frameworks often preceded broadband market development

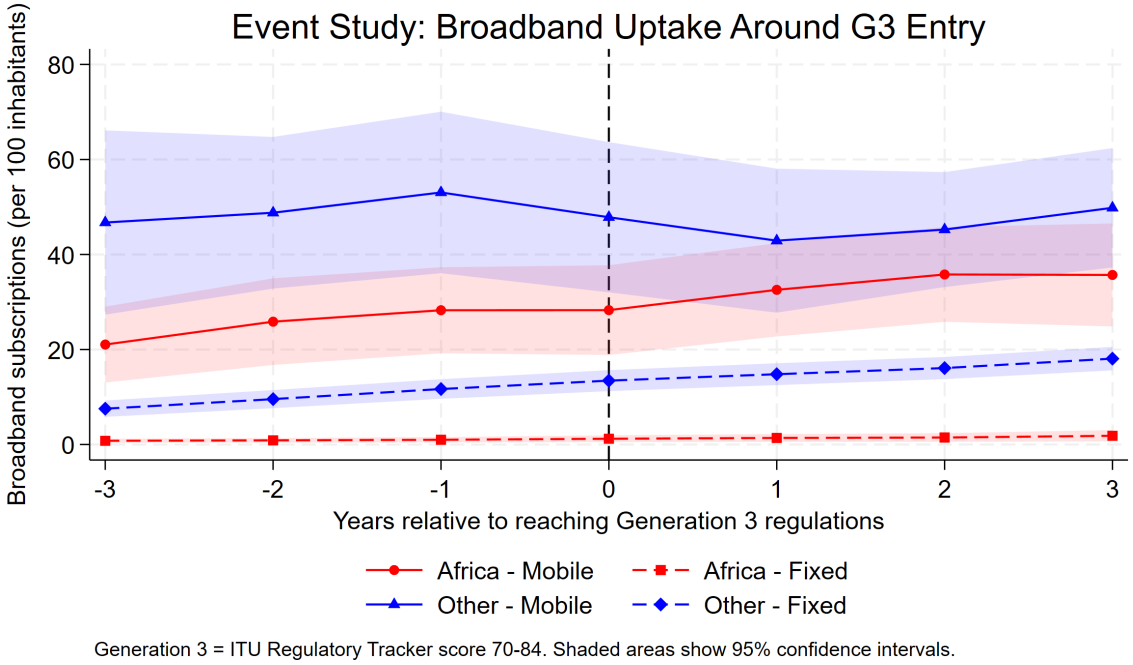
Regulations can influence connectivity through investment incentives, competition and pricing (Fink et al., 2003; Mishra & Kumar, 2023). Its effectiveness may also depend on the stage of market development and the institutional capacity available to implement and enforce regulatory provisions. The final fact therefore examines not only the level of regulation adopted by African countries, but also the stage of broadband market development at which more advanced regulatory frameworks were introduced.

Figure 6 presents an event study around the year in which countries first attained Generation 3 (G3) regulatory status, corresponding to an ITU ICT Regulatory Tracker score of 70–84.[5] The comparison focuses on broadband subscription levels around the year of regulatory adoption, rather than interpreting the event as a causal intervention.

At the time of adoption, African countries averaged approximately 28 mobile subscriptions and 1.2 fixed subscriptions per 100 inhabitants. The corresponding averages for non-African countries were approximately 48 and 13. Three years later, African countries had reached around 36 mobile and two fixed subscriptions, compared with approximately 49 and 18 elsewhere. The fixed-broadband difference is precisely estimated, while the mobile confidence intervals overlap, making the latter comparison less conclusive. Appendix Figure 11 shows a qualitatively similar

[5]G3 regulations encompass universal service obligations and consumer protection; G4 (shown in Appendix A) additionally covers data governance, cybersecurity and digital inclusion policies.

Figure 6: *African countries adopted G3 regulations at lower broadband density than other regions*



Note: The figure plots average broadband subscriptions per 100 inhabitants in the years surrounding the adoption of Generation 3 (G3) regulatory status (ITU ICT Regulatory Tracker score of 70–84). Time zero (vertical dashed line) denotes the year of G3 adoption. Solid lines represent mobile broadband (Africa in red, other regions in blue), while dashed lines represent fixed broadband. Shaded areas indicate 95% confidence intervals. The sample includes countries that achieved G3 status between 2007 and 2022. Data source: ITU.

pattern around G4 adoption, although the mobile gap is smaller.

These differences suggest that African countries often introduced more advanced regulatory frameworks at an earlier stage of broadband market development, when subscriber bases were smaller and fixed infrastructure less extensive. This timing may matter for the effectiveness of regulation. Frameworks designed to promote competition may have limited effects where market density is insufficient to sustain additional entry. Similarly, even well-designed rules may be difficult to implement where regulators lack the technical expertise and administrative resources required for effective enforcement (Cariolle, 2021). The descriptive evidence does not establish that early regulatory adoption caused weaker market development; rather, it highlights the possibility that regulatory effectiveness depends on the market and institutional conditions in which reforms are introduced.

2.2 What the facts leave unexplained

The five facts suggest that Africa's fixed-broadband shortfall cannot be attributed to a single constraint. The continent combines limited fixed-network development with relatively weak adoption, while the relationship between fixed-broadband prices and subscriptions is much less evident than for mobile broadband. Moreover, higher score on the regulatory tracker is associated with lower mobile prices but higher fixed-broadband prices in Africa, and advanced regulatory frameworks have often been introduced when broadband markets were still relatively small. These patterns point to a more complex relationship between regulation, market development and

connectivity than a simple infrastructure or affordability explanation would suggest.

Several complementary conditions may help explain these patterns. Appendix A documents four relevant associations. First, internet quality remains weaker in African economies, which tend to have lower speeds and higher latency; both are associated with lower uptake (Figures 7 and 8). Second, the availability of digital content may influence the value of connectivity: DDS imports as a share of GDP are positively associated with fixed subscriptions, and African economies tend to have low levels of both (Figure 9). Third, digital skills are weaker in African countries than their income levels alone would predict (Figure 12). Finally, electricity access remains a basic constraint on both the supply and use of digital connectivity. In 2022, approximately 50 per cent of the population in Sub-Saharan Africa had access to electricity, compared with more than 90 per cent in other developing regions. These relationships are descriptive rather than causal, but they identify complementary conditions that may shape the returns to connectivity investment and regulatory reform.

The evidence motivates the central hypothesis examined in the remainder of the paper: the contribution of connectivity and regulatory improvements to digital services trade depends on complementary infrastructure and institutional conditions. Section 3 examines the trade dimension, estimating the relationships between connectivity, regulation and DDS trade, and investigating why the regulatory association differs in Africa. Section 4 turns to broadband adoption, examining whether the limited diffusion of fixed broadband is more closely related to prices or to network availability.

3 A structural gravity analysis

To examine how digital connectivity and regulation are related to trade in services, we use a structural gravity framework.

3.1 Empirical Strategy

The empirical specification is based on the theoretical framework of Anderson & Van Wincoop (2003).

$$X_{ij} = \left(\frac{t_{ij}}{\Pi_i P_j}\right)^{(1-\sigma)} Y_i E_j \tag{1}$$

$$P_j^{1-\sigma} = \Sigma_i \left(\frac{t_{ij}}{\Pi_i}\right)^{(1-\sigma)} Y_i \tag{2}$$

$$\Pi_i^{1-\sigma} = \Sigma_j \left(\frac{t_{ij}}{P_j}\right)^{(1-\sigma)} E_j \tag{3}$$

Here, X_{ij} represents exports from country i to country j. Bilateral trade costs are captured by t_{ij}, while Y_i and E_j denote output in the exporting country and expenditure in the importing country respectively. Π_i and P_j are price indices which are weighted CES aggregates of the bilateral

trade costs with all other trading partners, referred to as the outward and inward multilateral resistance (MR) respectively. The Armington elasticity of substitution between services from different origins is denoted σ.

We use two sources of bilateral services trade data: the International Trade and Production Database for Estimation (ITPD-E) and the WTO–OECD Balanced Trade in Services (BaTiS) database. As the datasets differ in coverage and construction, we adopt a separate empirical specification for each. Both specifications are estimated using Poisson Pseudo Maximum Likelihood (PPML), which accommodates zero trade flows and is robust to heteroskedasticity.

Standard errors are clustered by country pair in ITPD-E and two ways, by exporter and importer, in BaTiS (Egger & Tarlea, 2015). This distinction matters because the variables of interest vary at the country-year level, while the trade observations are bilateral. In BaTiS, two-way clustering produces larger standard errors than pair clustering for every coefficient reported, typically by a factor of around two. In ITPD-E, the choice of clustering does not change the significance of the results. Appendix C reports both sets of standard errors for the headline specifications.

3.1.1 ITPD-E Specification

For ITPD-E, we use the three-way fixed-effects structure common in the structural gravity literature: exporter-year, importer-year and country-pair fixed effects, together with sector fixed effects.

$$X_{ijs,t} = \exp\left[\alpha_0 + \alpha_1 t_{ij,t} + \beta\, ICT_{j,t} \times INTL_{ij} + \nu_{i,t} + \lambda_{j,t} + \delta_{ij} + \zeta_s\right] + \epsilon_{ijs,t} \tag{4}$$

The coefficient of interest, β, captures the effect of an importer-specific connectivity or regulatory measure interacted with an indicator for international trade. The indicator equals one for cross-border trade and zero for domestic trade. Bilateral controls include time-varying factors such as free trade agreements and bilateral goods trade. Country-specific variables are entered on the importer side because, under this fixed-effects structure, their export and import effects cannot be separately identified (Beverelli et al., 2024). The resulting estimates capture changes in international trade relative to domestic sales.

We include five ITPD-E sectors classified as digitally deliverable: insurance and pension services (159), financial services (160), charges for the use of intellectual property n.i.e. (161), telecommunications, computer and information services (162), and other business services (163). Because sectoral information is incomplete for some countries and years, we pool these sectors and include sector fixed effects rather than aggregating them into a single DDS category (IMF-OECD-UNCTAD-WTO, 2023).

Following Heid et al. (2021), we include domestic trade flows to identify the effects of country-specific variables. Exporter-year and importer-year fixed effects absorb all time-varying country characteristics, including GDP, expenditure and the multilateral resistance terms. A positive coefficient therefore indicates a shift towards cross-border trade relative to domestic activity.

The ITPD-E domestic flows require some caution. They are constructed as gross output

less exports, and services-output coverage is uneven across African economies. Appendix B lists the African economies and years included in the estimation sample. Four economies—Egypt, Morocco, Nigeria and South Africa—account for 70 per cent of African observations, almost entirely through the domestic component.[6] Africa-specific estimates from ITPD-E consequently rely on a relatively narrow base. For this reason, we treat BaTiS as the primary source of evidence when interpreting Africa interactions, and use ITPD-E estimates as a comparison rather than as independent confirmation. BaTiS has its own limitations: about three-quarters of the cells for pairs involving an African economy are modelled using gravity-based methods (Table 13), although robustness checks show that excluding these observations does not substantially change the coefficients.

3.1.2 BaTiS Specification

BaTiS provides a balanced matrix of international services trade for more than 200 reporting economies and their partners, by sector, over 2005–2024. It does not contain domestic trade flows, so we cannot use the exporter-year and importer-year fixed effects included in ITPD-E. Instead, we include country-pair and sector fixed effects, standard gravity controls and an approximation of the time-varying multilateral resistance terms.

$$X_{ijs,t} = \exp\left[\alpha + \beta_1 ICT_{i,t} + \beta_2 ICT_{j,t} + \mathbf{z}'_{i,t}\boldsymbol{\gamma}_1 + \mathbf{z}'_{j,t}\boldsymbol{\gamma}_2 + \phi\, RTA_{ij,t} + \rho\, MR_{ij,t} + \delta_{ij} + \zeta_s\right] + \epsilon_{ijs,t} \tag{5}$$

The country-specific controls include log GDP and log population for both exporters and importers. Together, these variables allow income and market size to enter separately. Country-pair fixed effects absorb distance and other time-invariant bilateral characteristics, as well as time-invariant exporter and importer characteristics. The latter are therefore not separately estimated.

The multilateral resistance term, $MR_{ij,t}$, is a constructed regressor rather than a fixed effect. Following Baier & Bergstrand (2009), we approximate the multilateral resistance terms using a Taylor-series expansion of GDP-weighted averages of bilateral trade costs. The exporter and importer components enter as a single combined term and are therefore estimated with one coefficient. The terms are calculated over the full universe of country pairs, rather than only the estimation sample, so that the GDP weights sum correctly.

The DDS sectors in BaTiS include insurance and pension services [SF], financial services [SG], charges for the use of intellectual property n.i.e. [SH], telecommunications, computer and information services [SI], other business services [SJ], and personal, cultural and recreational services [SK].

Although BaTiS provides a balanced matrix, not all values are directly reported. Roughly seven in ten cells in the DDS matrix are modelled rather than reported or estimated from reported information. Since this modelling relies on gravity-based methods, estimating a gravity model on these cells could partly recover the assumptions used to generate the data. We therefore repeat the analysis using only cells that are not modelled. The results are preserved under this restriction

[6] This concentration reflects the availability of national accounts output series in the source data.

and are often stronger. The restriction also appears broadly neutral with respect to observable characteristics: normalised differences between retained and excluded cells are below 0.09, with no clear gradient in the modelled share across the income distribution. Appendix D reports the restricted estimates in full and Table 13 in Appendix B documents the composition of the two samples. The main text reports the full BaTiS sample, which is roughly four times larger.

3.1.3 Interpreting the Two Specifications

The two datasets provide complementary but different perspectives on the relationship between country conditions and DDS trade. ITPD-E includes domestic as well as international trade. Its coefficient captures whether a change in connectivity or regulation is associated with a shift towards international trade relative to domestic sales. The specification absorbs other time-varying country characteristics through exporter-year and importer-year fixed effects, but it cannot identify exporter- and importer-side effects separately (Beverelli et al., 2024).

BaTiS contains only international trade. Its country-pair fixed effects absorb time-invariant bilateral characteristics, while the multilateral resistance terms and country-level controls account for some time-varying factors. The explanatory variables are identified from changes within country pairs over time. Unlike ITPD-E, BaTiS estimates exporter and importer effects separately: a positive exporter coefficient indicates that an improvement in the origin country is associated with higher exports, while a positive importer coefficient indicates higher imports. However, because time-varying country characteristics are not fully absorbed, BaTiS estimates are more exposed to country-level confounding than those from ITPD-E.

We do not include year fixed effects in BaTiS. Connectivity, regulatory scope and DDS trade all trend upwards over the sample period, and we are interested in whether improvements in connectivity and regulation are associated with changes in trade over time. Year effects would remove this common variation and leave only deviations from the global trend. The multilateral resistance approximation, together with GDP and population controls, accounts for some of the aggregate forces that might otherwise confound the estimates. ITPD-E provides a complementary specification in which exporter-year and importer-year effects absorb common and country-specific trends.

The coefficients from the two datasets are therefore not directly comparable in magnitude. A factor could increase both domestic and international trade, but increase domestic trade by more. In that case, the ITPD-E estimate could be negative even if the factor raises cross-border trade in the BaTiS specification. Agreement across the datasets is useful corroborating evidence, while differences help distinguish relationships with the relative importance of cross-border trade from relationships with the level of bilateral flows.

Our main explanatory variables are fixed and mobile broadband subscriptions, internet speed and latency, and the ITU Regulatory Tracker, which serves as a proxy for regulatory scope. Connectivity variables are transformed using $\ln(1 + x)$ to retain observations with zero values, which is particularly relevant for fixed broadband penetration in lower-income countries.[7] The ITU Regulatory Tracker is rescaled to range from zero to one.

[7] The $\ln(1+x)$ transformation retains zero observations and avoids excluding countries with nascent infrastructure. Its coefficients should not be interpreted as conventional elasticities with respect to the original variable: the percentage change in the outcome associated with a change in x depends on the initial value of x.

3.2 Connectivity as Productive Infrastructure

A first policy consideration is that expanding internet access and building the infrastructure needed to produce and trade digital services are not necessarily the same thing. The results suggest that broadband infrastructure matters for DDS trade, but that fixed broadband has a stronger and more consistent association with trade than mobile broadband. This distinction is relevant for governments deciding how to balance the expansion of mobile access with investment in fixed networks.

We first examine the relationship between digital infrastructure and trade in DDS. Table 2 summarises the main estimates for broadband penetration and internet quality across the two datasets. Full regression results are reported in Appendix C.

Table 2: *Digital Connectivity Effects on Services Trade: Summary of Main Coefficients*

	ITPD-E		BaTiS	
Variable	Coef.	Obs.	Coef. (Exp./Imp.)	Obs.
Penetration rates:				
Fixed broadband	0.643***	414,226	0.135***/−0.000	3,721,650
Mobile broadband	0.334***	266,970	0.025/0.029	3,019,188
Internet speed:				
Fixed download speed	0.215***	216,506	0.054/0.022	2,211,222
Mobile download speed	0.158***	81,706	0.074**/0.048	1,256,292
Latency:				
Fixed latency	−0.375***	172,979	−0.077/−0.034	1,424,568
Mobile latency	−0.317***	81,706	−0.042/−0.050	1,256,292

Notes: ITPD-E coefficients report effects relative to domestic trade through interactions with the international-trade indicator. BaTiS coefficients report separate exporter and importer effects estimated from a single regression, so the observation count applies to both margins. All connectivity variables are transformed using $\ln(1+x)$. All specifications include the appropriate fixed effects. * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Fixed Broadband and the Capacity to Export

The estimates point to a stronger association between fixed broadband and DDS trade than between mobile broadband and DDS trade. In ITPD-E, the coefficients are positive and statistically significant for both technologies, but the fixed broadband coefficient (0.643) is almost twice the mobile broadband coefficient (0.334). In BaTiS, fixed broadband is positive and statistically significant on the exporter side (0.135), while its importer-side coefficient is effectively zero. Mobile broadband is positive but not statistically significant on either margin.

The clearest common finding is therefore the stronger relationship between fixed broadband and DDS trade, particularly on the supply side. The distinction between the two datasets remains important. ITPD-E measures international trade relative to domestic sales, whereas BaTiS estimates changes in bilateral trade flows. The larger ITPD-E coefficient does not mean that fixed broadband has a correspondingly larger effect on the level of exports. It indicates a stronger association with the allocation of services trade towards international markets relative to domestic

sales. BaTiS, in turn, suggests that fixed broadband is associated with higher exports, although the estimates are less precise.

This pattern is consistent with the technical requirements of producing and exporting digital services. Export-oriented production may depend on reliable, high-capacity connections and low latency, while the connectivity needed to consume some digital services may be less demanding. Mobile networks are important for extending internet access, but fixed infrastructure can provide the stable capacity required by data-intensive activities. Fixed broadband also supports mobile networks by providing fibre-optic backhaul for 4G and 5G base stations (Janevski, 2015). Its role is therefore not limited to households and businesses with fixed subscriptions; it can also underpin the quality and capacity of mobile services.

For policy, the results point to the importance of treating fixed and mobile infrastructure as complementary rather than interchangeable. Expanding mobile coverage remains important for broadening access, but it should not substitute for investment in fixed networks and the backbone infrastructure needed to support high-capacity connectivity. In practical terms, this means that broadband strategies aimed at developing DDS exports should consider not only the number of people connected, but also the capacity, reliability and quality of the networks available to firms.

The estimates do not identify which particular investment model or technology mix is most cost-effective. Nor do they establish that fixed broadband investment alone will generate higher exports. They do, however, suggest that a strategy focused exclusively on expanding basic mobile access may leave an important constraint on digitally deliverable services production unresolved.

Connection Quality Also Matters

The results for internet speed and latency reinforce the importance of looking beyond subscription rates. In ITPD-E, download speed is positive and statistically significant for both fixed and mobile connections, with coefficients of 0.215 and 0.158, respectively. In BaTiS, fixed download speed is positive but not statistically significant on the exporter margin, while mobile download speed is positive and significant there (0.074). The two BaTiS coefficients are close relative to their standard errors, so the estimates do not provide a clear basis for concluding that one type of connection matters more than the other.

Latency has the expected negative sign in ITPD-E and is statistically significant for both fixed and mobile connections, with coefficients of -0.375 and -0.317. The BaTiS latency coefficients are also negative, ranging from -0.034 to -0.077, but none is statistically significant. The quality indicators are available for substantially fewer observations, and latency varies relatively little within country pairs over the period for which it is observed. The BaTiS estimates are therefore too imprecise to confirm or reject the ITPD-E results.

Taken together, the results suggest that the policy objective should not be defined only in terms of expanding subscriptions or nominal coverage. Network quality also matters, although the evidence on speed and latency is less consistent across datasets. For governments, this strengthens the case for monitoring the performance of broadband networks alongside access indicators. The estimates do not identify specific service-quality targets, but they suggest that the capacity and reliability of connections are relevant to the development of DDS trade.

3.3 Telecommunication Regulations and the African Puzzle

Connectivity creates the technical possibility of trading digital services, but the regulatory environment also shapes whether firms can enter markets, compete and deliver services across borders. Regulation can support investment and competition by establishing predictable rules, addressing anti-competitive conduct and facilitating interconnection. However, the presence of a formal regulatory framework does not necessarily mean that these objectives are achieved in practice. The effectiveness of regulation may depend on the capacity of public institutions to implement and enforce it.

Table 3: *ITU Regulatory Tracker Effects: Summary of Main Results*

	ITPD-E		BaTiS	
Specification	Coef.	Obs.	Coef. (Exp/Imp)	Obs.
Baseline:				
ITU Tracker	3.833***	314,018	0.464***/0.244	3,576,762
Africa heterogeneity:				
ITU Tracker	3.843***	314,018	0.469***/0.311	3,576,762
ITU × Africa	−10.526***		−0.822*/−1.451***	

Notes: ITPD-E reports effects relative to domestic trade (interaction with an INTL dummy). BaTiS reports separate effects for exporter and importer. The ITU regulatory tracker is rescaled to range between 0 and 1. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3 reports the relationship between the ITU Regulatory Tracker and DDS trade. The global estimates are positive in ITPD-E (3.833) and on the BaTiS exporter margin (0.464), while the BaTiS importer estimate is not statistically significant. In ITPD-E, a 0.02 increase in the rescaled Tracker, equivalent to two points on the original scale, is associated with approximately 8 per cent higher international trade relative to domestic sales.

The estimates for African economies differ. The interaction between the Tracker and the Africa indicator is negative in both datasets. It is significant at the one per cent level in ITPD-E and on the BaTiS importer margin, and at the ten per cent level on the BaTiS exporter margin. In ITPD-E, the interaction of −10.526 more than offsets the baseline coefficient, producing a net estimate of −6.68 for African economies. In BaTiS, the corresponding net estimates are −0.35 for African exporters and −1.14 for African importers. These estimates do not imply that regulation itself reduces trade. They indicate that the positive relationship observed in the broader sample is weaker, and in some specifications negative, for African economies.

We consider three possible explanations in turn: an implementation gap between formal regulatory frameworks and their effective enforcement; the absence of complementary factors required for regulations to generate trade gains; and a measurement problem, whereby the ITU Tracker does not capture regulation as it operates in African markets.

Hypothesis 1: Regulation Needs the Capacity to Be Implemented

One possible reason is that regulatory frameworks may be adopted before the institutions and market conditions needed to implement them are in place. We examine this possibility by

interacting the ITU Tracker with government effectiveness, measured using the World Bank's Worldwide Governance Indicators. This measure captures the quality of public services and the civil service, as well as policy implementation and the credibility of government commitments. It is rescaled from its original percentile-rank scale to range from zero to one.

Table 4: *ITU Regulatory Tracker: Implementation Gap*

	ITPD-E		BaTiS	
Specification	Coef.	Obs.	Coef. (Exp/Imp)	Obs.
Implementation gap (Gov. Effectiveness):				
ITU Tracker	−0.558	309,038	−0.214/−1.053***	3,275,046
Gov. Effectiveness	−5.690***		−0.427/−1.607***	
ITU × Gov. Eff.	4.909***		0.819/2.054***	
With Africa interactions:				
ITU × Gov. Eff.	4.680***	309,038	0.727/1.742***	3,275,046
Gov. Eff. × Africa	25.731***		0.801/−0.714	
ITU × Gov. Eff. × Africa	−26.984***		−1.668/1.015	

Notes: ITPD-E reports effects relative to domestic trade (interaction with an INTL dummy). BaTiS reports separate effects for exporters and importers. The ITU regulatory tracker and the government effectiveness indicator are rescaled to range between 0 and 1. Specifications with Africa interactions include the full set of constituent lower-order interactions. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The interaction between regulatory scope and government effectiveness is positive and statistically significant in ITPD-E (4.909) and on the BaTiS importer margin (2.054). This indicates that the relationship between regulation and DDS trade becomes more positive as government effectiveness increases. The main ITU coefficient in these specifications should not be interpreted on its own: it represents the marginal effect of regulation when government effectiveness is zero, which lies outside the observed range of the data.

In a specification that includes regulations R, government effectiveness K, and their interaction, the marginal effect of regulation is $\beta_1 + \beta_3 K$. The positive interaction therefore means that the estimated relationship between regulation and trade improves as implementation capacity rises. The marginal effect of government effectiveness is also conditional on regulatory scope, given by $\beta_2 + \beta_3 R$. The results point to a complementary relationship: formal rules and the capacity to put them into practice are associated with better trade outcomes when they are present together.

The estimated level of government effectiveness at which the marginal relationship between regulation and trade changes sign is 0.51 for BaTiS importers in the pooled sample and 0.11 in ITPD-E. When the relationship is allowed to differ for Africa (the specification with Africa interactions), the switch point is about 0.46 for non-African importers and about 0.81 for African importers. These switch points are ratios of estimated coefficients, so their uncertainty depends on both estimates, and they should be read as indicative rather than as policy thresholds.

For policymakers, the central implication is that regulatory reform should include the institutions and processes needed to make new rules operational. This involves more than passing legislation or adopting a regulatory framework. It requires regulators with adequate technical expertise and resources, clear responsibilities, the ability to monitor compliance, and the capacity to enforce decisions. It also requires secondary rules and administrative procedures that allow firms and consumers to use the rights established in primary legislation. These are practical implications of the implementation relationship; the regressions do not separately estimate the effects of individual institutional reforms.

Evidence from the World Bank–WTO pilot reviews of six African economies illustrates the distinction between adopting rules and implementing them. The reviews find that legislation is often in place while secondary regulation and the institutions needed to implement it remain nascent. All six economies had recently adopted data protection laws, but only Kenya had established a data protection agency. E-signature laws had also seen limited uptake, partly because implementing rules were lacking (World Bank & WTO, 2025). Although this evidence concerns digital-trade regulation more broadly, it illustrates why the adoption of a law may not be sufficient to change the conditions facing firms. The Africa-specific interaction results require more caution. In BaTiS, neither triple interaction between regulation, government effectiveness and the Africa indicator is statistically significant. The African importer relationship nevertheless remains more negative through the lower-order terms. The implied marginal effect of regulation for African importers is

$$(-0.808 - 1.429) + (1.742 + 1.015) \times Gov.\ Eff.,$$

which changes sign at a government effectiveness level of about 0.81, compared with about 0.46 for non-African importers. This suggests that African importers may require higher implementation capacity before regulatory scope is positively associated with trade. The estimated difference is informative, but it should not be read as a precise threshold for reform.

The ITPD-E triple interaction is large and statistically significant (-26.984), but it is offset by a nearly equal and opposite government-effectiveness-by-Africa interaction (25.731). Taken together, the terms imply that the regulatory relationship becomes more negative as government effectiveness rises in African economies, an economically counterintuitive result. Given the narrow African base in ITPD-E, these offsetting estimates are likely to be poorly identified. We therefore rely primarily on BaTiS when interpreting Africa-specific differences.

The evidence thus supports a general policy lesson more clearly than a precise Africa-specific threshold: regulatory frameworks are more positively associated with DDS trade where public institutions are better able to implement them. Governments should therefore treat regulatory capacity as part of digital-trade policy, rather than as a separate governance issue. The results do not establish which institutional reform would have the largest effect, but they caution against measuring regulatory progress solely by the adoption of laws or the formal scope of a regulatory framework.

Hypothesis 2: Coordinate Digital Policy with Complementary Investments

Regulatory capacity is only one part of the enabling environment for DDS trade. Firms also need reliable electricity, workers with relevant skills, and broadband infrastructure capable of supporting digital production. These conditions are closely related: connectivity is less useful when electricity is unreliable, while the benefits of digital infrastructure may be limited if firms cannot recruit workers with the necessary skills. Regulation may similarly have limited effect where the underlying infrastructure and market capabilities needed for competition are absent.

We examine these relationships by interacting the ITU Tracker with four complementary factors: electricity access, secondary school enrolment, fixed broadband penetration and mobile broadband penetration. Table 5 reports the global results, while Table 6 allows the relationships to differ for African economies. The full regression results are reported in Appendix C.

The results indicate that regulatory scope is more positively associated with DDS trade when

Table 5: *Testing Complementarity: Global Estimates*

	ITPD-E	BaTiS	
	Coef.	Exporter	Importer
Complement: electricity access			
ITU Tracker	−22.824***	−0.667	−2.001***
	(5.534)	(0.861)	(0.622)
Electricity access	−15.605***	−1.024	−1.915***
	(3.744)	(0.686)	(0.484)
ITU × Electricity	26.643***	1.163	2.353***
	(5.536)	(0.876)	(0.645)
Switch points, ITU / complement			0.85 / 0.81
Observations	314,018	3,385,638	
Complement: secondary education enrolment			
ITU Tracker	−5.566***	−0.947	−1.179***
	(1.679)	(1.029)	(0.455)
Secondary enrolment	−7.696***	−1.394*	−1.220***
	(1.393)	(0.816)	(0.446)
ITU × Education	8.615***	1.418	1.404***
	(1.516)	(0.993)	(0.456)
Switch points, ITU / complement			0.84 / 0.87
Observations	282,387	1,843,584	
Complement: fixed broadband penetration			
ITU Tracker	0.494	−0.011	−0.283
	(0.544)	(0.216)	(0.196)
Fixed broadband	−2.172	−0.507	−2.110***
	(1.976)	(0.964)	(0.774)
ITU × Fixed BB	5.243**	1.437	2.887***
	(2.089)	(0.988)	(0.803)
Switch points, ITU / complement			0.10 / 0.73
Observations	310,226	3,202,170	
Complement: mobile broadband penetration			
ITU Tracker	2.506***	0.056	−0.163
	(0.622)	(0.255)	(0.254)
Mobile broadband	−0.081	−0.272	−0.405**
	(0.452)	(0.220)	(0.185)
ITU × Mobile BB	0.456	0.463**	0.631***
	(0.528)	(0.225)	(0.213)
Switch points, ITU / complement			0.26 / 0.64
Observations	263,394	2,895,192	

Notes: Each block is a separate regression. ITPD-E reports effects relative to domestic trade (all terms interacted with an INTL dummy); BaTiS reports separate exporter and importer effects from a single regression, so the observation count applies to both margins. The ITU Tracker and all complementary indicators are rescaled to the unit interval. Main effects are evaluated at a zero value of the interacted variable, which lies outside the observed range, and are reported so that marginal effects and switch points can be computed. The switch points are $-\beta_{ITU}/\beta_{ITU\times Comp}$ and $-\beta_{Comp}/\beta_{ITU\times Comp}$ evaluated on the BaTiS importer margin, that is, the level of the complement at which regulation turns trade-enhancing and the level of regulation at which the complement turns trade-enhancing. Both are ratios whose denominators are estimated and should not be read as point estimates. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

complementary infrastructure and human capital are more developed. On the BaTiS importer margin, the interaction between the Tracker and each of the four complementary factors is positive and statistically significant. In ITPD-E, the interactions are positive and significant for electricity, education and fixed broadband, but not for mobile broadband. The pattern suggests that regulation and these complementary conditions tend to reinforce one another, although the strength and precision of the estimates differ across datasets.

The interaction terms can be interpreted in both directions. For example, on the BaTiS importer margin, the marginal relationship between regulatory scope and imports is $-2.001 + 2.353 \times \textit{Electricity}$, while the marginal relationship between electricity access and imports is $-1.915 + 2.353 \times \textit{ITU}$. The estimated switch points are 0.85 for electricity access and 0.81 for regulatory scope. The corresponding pairs are 0.84 and 0.87 for education, 0.10 and 0.73 for fixed broadband, and 0.26 and 0.64 for mobile broadband.

These estimates are useful for illustrating that the relationship between regulation and trade is conditional on the wider environment. They should not, however, be treated as precise policy thresholds. The switch points are ratios of estimated coefficients, and the tables do not establish that the true relationship changes sign at exactly these values. Nor do they imply that governments should target a single indicator in isolation. The broader message is that improvements in regulatory scope are more positively associated with trade when electricity, skills and broadband infrastructure are also in place.

Fixed broadband is particularly notable in the BaTiS results. Its interaction with regulatory scope is positive and statistically significant on the importer margin (2.887). The estimated switch point for fixed broadband is also relatively low (0.10), suggesting that the relationship between regulatory scope and imports becomes positive at comparatively modest levels of fixed broadband penetration in the global sample. This is consistent with the earlier results on the role of fixed broadband in supporting DDS trade.

For policymakers, the results point to the importance of coordinating investments that are often planned and implemented separately. Digital strategies need to connect broadband expansion with electricity provision, education and skills development. This does not mean that every country must invest equally in all four areas or that the paper identifies an optimal order of investment. Rather, the estimates suggest that progress in one area may yield weaker trade-related returns when other basic conditions remain absent. A broadband strategy, for example, is unlikely to deliver its full potential for digital services firms if electricity supply is unreliable or if the workforce lacks the skills needed to use digital technologies productively.

The Africa interactions indicate that the negative relationship between regulatory scope and DDS trade persists when these complementary factors are included. On the BaTiS importer margin, the lower-order ITU-by-Africa interaction is negative and statistically significant in three of the four specifications: education (-3.469), fixed broadband (-0.766) and mobile broadband (-1.055). The electricity interaction is not statistically significant. The ITPD-E estimates are also negative and significant for education (-17.384) and fixed broadband (-5.865).

The estimated switch points help illustrate the scale of the difference. For non-African importers, the level of each complementary factor at which the marginal relationship between regulation and imports becomes positive lies within the unit interval in all four specifications: 0.81 for electricity, 0.72 for education, 0.08 for fixed broadband and 0.14 for mobile broadband. For African importers, combining the lower-order and triple interactions moves three of the four

Table 6: *Testing Complementarity: Africa Heterogeneity*

	ITPD-E	BaTiS	
	Coef.	Exporter	Importer
Complement: electricity access			
ITU Tracker	−17.567*	−1.880**	−1.539
	(9.335)	(0.750)	(0.971)
ITU × Electricity	21.385**	2.385***	1.893**
	(9.329)	(0.762)	(0.952)
ITU × Africa	−19.954	2.860**	0.355
	(12.546)	(1.397)	(1.080)
ITU × Electricity × Africa	30.455*	−4.207**	−1.554
	(16.028)	(1.701)	(1.388)
Switch points, non-Africa / Africa			0.81 / 3.50
Observations	314,018	3,385,638	
Complement: secondary education enrolment			
ITU Tracker	−5.405***	−0.888	−0.568
	(1.713)	(1.097)	(0.425)
ITU × Education	8.468***	1.354	0.790*
	(1.546)	(1.064)	(0.456)
ITU × Africa	−17.384**	−0.134	−3.469***
	(8.281)	(1.114)	(1.250)
ITU × Education × Africa	27.763**	−0.460	2.788**
	(12.631)	(1.138)	(1.332)
Switch points, non-Africa / Africa			0.72 / 1.13
Observations	282,387	1,843,584	
Complement: fixed broadband penetration			
ITU Tracker	0.528	0.018	−0.199
	(0.547)	(0.226)	(0.206)
ITU × Fixed BB	5.142**	1.340	2.580***
	(2.096)	(1.012)	(0.787)
ITU × Africa	−5.865***	−0.310	−0.766*
	(2.176)	(0.402)	(0.455)
ITU × Fixed BB × Africa	236.880	2.351	3.475
	(506.343)	(3.095)	(6.045)
Switch points, non-Africa / Africa			0.08 / 0.16
Observations	310,226	3,202,170	
Complement: mobile broadband penetration			
ITU Tracker	2.526***	0.073	−0.080
	(0.624)	(0.263)	(0.262)
ITU × Mobile BB	0.446	0.452**	0.587***
	(0.528)	(0.229)	(0.217)
ITU × Africa	10.182	−0.083	−1.055**
	(6.795)	(0.668)	(0.424)
ITU × Mobile BB × Africa	−39.632*	−0.176	0.194
	(20.946)	(0.494)	(0.553)
Switch points, non-Africa / Africa			0.14 / 1.45
Observations	263,394	2,895,192	

Notes: Each block is a separate regression and includes the full set of constituent lower-order interactions, so that the quadruple (ITPD-E) or triple (BaTiS) term measures the difference in the regulation–complement interaction for Africa. The $Complement \times Africa$ terms are estimated but omitted here because they do not enter the marginal effect of regulation; they are reported in Appendix C. Because these are augmented specifications, the coefficients differ from their counterparts in Table 5. The switch point is the level of the complement at which the marginal effect of regulation on imports changes sign, evaluated on the BaTiS importer margin: for non-African importers it is $-\beta_{ITU}/\beta_{ITU\times Comp}$, and for African importers $-(\beta_{ITU}+\beta_{ITU\times Afr})/(\beta_{ITU\times Comp}+\beta_{ITU\times Comp\times Afr})$. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

estimated switch points outside this interval: 3.50 for electricity, 1.13 for education and 1.45 for mobile broadband. The estimated marginal relationship therefore does not become positive within the observed range of these indicators. Fixed broadband is the exception. Its African switch point is 0.16, compared with 0.08 for non-African importers. However, 0.16 is well above the African average penetration rate of around 0.02, and the triple interaction underlying this estimate is imprecise (3.475, with a standard error of 6.045).

These results suggest that including the four complementary factors does not remove the weaker African relationship between regulatory scope and DDS trade. They also indicate that the conditions under which regulation is positively associated with imports may be harder to reach in African economies. But the switch points are descriptive features of the fitted relationships, not targets that can be translated directly into investment plans. In particular, they do not establish that increasing electricity access, education or broadband to a specified level would, by itself, reverse the estimated relationship.

The triple interactions provide limited evidence about which complement accounts for the African difference. In BaTiS, only the electricity exporter interaction (-4.207) and the education importer interaction (2.788) are statistically significant, and they have opposite signs. The ITPD-E results are also mixed: the electricity and education triple interactions are positive, while the fixed-broadband interaction is very large but highly imprecisely estimated (236.880, with a standard error of 506.343). Since fixed broadband penetration in Africa averages around two per cent, the relevant interactions are estimated near the bottom of the observed range, where precision is limited. The narrow African base in ITPD-E further constrains the estimation of higher-order interactions.

The results do not therefore identify one particular missing investment as the source of the African difference. They support a broader conclusion: regulatory scope is more positively associated with DDS trade when combined with infrastructure and human capital, while the negative African relationship persists across the specifications. For policy, this favours an integrated approach. Governments need to consider the interaction between connectivity, electricity, skills and regulatory implementation when setting digital-development priorities, rather than treating each as a stand-alone intervention.

Hypothesis 3: How Regulation Is Measured

The preceding results point to the importance of regulatory implementation and complementary investments. A further question is whether the measured relationship between regulation and trade depends on the way regulatory scope is defined. This matters for policy because progress in regulatory reform is often assessed through formal indicators of laws, institutions and market rules. Such indicators may not fully capture how regulations operate in practice or whether they are appropriate for the conditions of a particular market.

We examine this issue using three alternative approaches. First, following Bergstrand & Paniagua (2024), we estimate the four ITU regulatory clusters separately while controlling for the depth of the remaining three. This allows us to assess whether the results are concentrated in particular regulatory dimensions. We rescale each component by dividing by 100 so that the indices are expressed in comparable units. Second, we construct a bilateral measure of regulatory heterogeneity based on the cumulative absolute difference across the 50 ITU Tracker indicators between trading partners. This tests whether regulatory differences between countries

are associated with lower trade. Third, we use the OECD Digital Services Trade Restrictiveness Index (DSTRI) as an alternative measure. The DSTRI captures barriers to digital services trade across several areas, including infrastructure restrictions, electronic transactions, payment systems and intellectual property rights. It ranges from zero to one, with higher values indicating greater restrictiveness.

Table 7: *Measurement Hypothesis: Testing Alternative Regulation Measures*

	ITPD-E		BaTiS	
Measure	Coef.	Obs.	Coef. (Exp/Imp)	Obs.
ITU Cluster C1 (Regulatory Authority):				
Cluster C1	1.684	314,018	−1.704**/−0.002	3,576,762
Other clusters (depth)	4.121***		0.870***/0.234	
ITU Cluster C2 (Regulatory Mandate):				
Cluster C2	3.407**	314,018	0.555/1.267	3,576,762
Other clusters (depth)	3.929***		0.450/0.040	
ITU Cluster C3 (Regulatory Regime):				
Cluster C3	3.905***	314,018	1.798***/0.602*	3,576,762
Other clusters (depth)	3.764***		−0.485/−0.126	
ITU Cluster C4 (Competition Framework):				
Cluster C4	4.905***	314,018	−0.562/−0.950	3,576,762
Other clusters (depth)	3.548***		0.813***/0.654**	
Bilateral regulatory heterogeneity:				
ITU heterogeneity	0.147	265,804	−0.027	3,190,200
DSTRI (restrictiveness):				
DSTRI	2.117***	132,310	0.066/−0.346	469,920

Notes: ITPD-E reports effects relative to domestic trade (interaction with an INTL dummy). BaTiS reports separate effects for exporters and importers. ITU tracker cluster indices are rescaled by dividing by 100. Depth is defined as the sum of the other three ITU clusters. The regulatory heterogeneity index captures the cumulative absolute differences between trading partners. The DSTRI index is the OECD Digital STRI, with higher values indicating greater restrictiveness. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The global results vary across regulatory dimensions. In ITPD-E, Regulatory Mandate (C2), Regulatory Regime (C3) and Competition Framework (C4) have positive and statistically significant coefficients when controlling for the depth of the other clusters.[8] Regulatory Authority (C1) is not individually significant, although the combined depth of the other three clusters remains positive and significant. Evaluated over each component's achievable range, the estimated effects are 0.34 log points for C1, 0.75 for C2, 1.17 for C3 and 1.37 for C4. These are smaller than the raw coefficients suggest. For comparison, the aggregate Tracker has an estimated effect of 3.833 log points over its full range. The four component estimates sum to 3.63 log points when evaluated over their respective ranges. This approximate correspondence provides a useful consistency check, although the components are estimated in separate specifications and the comparison should not be treated as an exact decomposition.

In BaTiS, the results are less uniform. Regulatory Regime (C3) is the only component with a positive and statistically significant exporter-side coefficient (1.798), equivalent to around 0.54 log points over its range. Its importer-side coefficient is positive but only marginally significant

[8]Cluster 4 includes measures that may raise endogeneity concerns, such as actual levels of competition across market segments and the participation of foreign firms in domestic markets. Results for this cluster should therefore be interpreted with caution.

(0.602). Regulatory Authority (C1) is negative and significant on the exporter margin, while the coefficients for Competition Framework (C4) are negative but not statistically significant.

Table 8: *Measurement Hypothesis: Africa Heterogeneity by Regulatory Component*

	ITPD-E		BaTiS	
Component	Cluster × Afr	Depth × Afr	Cluster × Afr (E/I)	Depth × Afr (E/I)
C1: Authority	−61.842***	−4.944	3.924***/2.300	−1.725***/−2.174***
	(23.037)	(3.424)	(1.285)/(1.463)	(0.525)/(0.687)
C2: Mandate	−135.590***	−8.248***	−1.468/1.911	−0.720/−1.939***
	(44.720)	(1.982)	(1.919)/(1.780)	(0.699)/(0.712)
C3: Regime	−0.786	−24.329***	−2.961**/−3.552***	0.764/0.203
	(6.391)	(7.900)	(1.190)/(0.952)	(0.491)/(0.631)
C4: Competition	−0.429	−13.842**	0.033/−1.591	−1.097*/−1.397**
	(13.588)	(5.772)	(1.032)/(1.420)	(0.634)/(0.625)
Regulatory heterogeneity	–	−0.079	–	0.274
		(0.357)		(0.197)
DSTRI (restrictiveness)	–	3.848	–	1.018**/1.143**
		(3.710)		(0.501)/(0.502)

Notes: ITU tracker cluster indices are rescaled by dividing by 100. Depth is defined as the sum of the other three ITU regulatory clusters. The regulatory heterogeneity index captures cumulative absolute differences across the 50 ITU tracker indicators between trading partners. The DSTRI index is the OECD Digital STRI, with higher values indicating greater restrictiveness. Triple interactions test Africa-specific heterogeneity. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The Africa interactions provide a more differentiated picture. In BaTiS, the Africa interaction for Regulatory Regime (C3) is negative and statistically significant on both the exporter and importer margins (-2.961 and -3.552, respectively). This contrasts with its positive global association, particularly on the export side. The net C3 coefficient for African importers is $0.774 - 3.552 = -2.78$. Across the component's range of zero to 0.30, this corresponds to an estimated effect of approximately -0.83 log points. For comparison, the net effect of the aggregate Tracker on African imports is -1.14 across its full unit range.

This result suggests that the relationship between regulation and trade may depend on the type of rules being introduced and the market conditions in which they operate. C3 includes interconnection rules, unbundling requirements and licensing regimes. These provisions are intended to support competition, but their effectiveness may depend on the presence of viable entrants and a market large enough to sustain multiple operators. Where these conditions are absent, the expected gains from such rules may not materialise. The result is consistent with the broader argument that regulatory reforms need to be adapted to market conditions, but it does not establish that these particular rules reduce trade.

The results also show that the African difference is not confined to C3. The interactions between Africa and regulatory depth are negative and significant for C1, C2 and C4 in at least one BaTiS margin, indicating that greater depth in other regulatory components may also be associated with weaker trade outcomes. This is consistent with the broader institutional context. African members' WTO telecommunications commitments provide, on average, about half the market access guaranteed by the full membership, and African economies account for 12 of the 106 members that have subscribed to the Telecommunications Reference Paper, which covers interconnection and

anti-competitive practices (World Bank & WTO, 2023).

The bilateral regulatory heterogeneity measure does not provide clear support for the view that regulatory differences between trading partners constrain DDS trade. Its coefficient is small and statistically insignificant in ITPD-E, and the Africa interactions are also insignificant. The results therefore neither confirm nor rule out regulatory misalignment as an important trade barrier.

The DSTRI results require a different interpretation. In ITPD-E, greater restrictiveness is positively associated with international trade relative to domestic trade (2.117), while the Africa interaction is positive but statistically insignificant. In BaTiS, the baseline coefficients are small and insignificant, but the Africa interactions are positive and significant on both margins (1.018 for exporters and 1.143 for importers). One possible explanation is that the DSTRI includes restrictions on commercial presence (mode 3), so greater restrictiveness may shift some services delivery towards cross-border trade (Avendano & Nordås, 2026). This is a possible explanation rather than a mechanism established by the estimates.

An additional specification controlling for applied ICT goods tariffs leaves the main regulatory findings largely unchanged. The estimated tariff effects differ substantially across datasets (See Tables 26 and 27 in Appendix C).

Summary

Taken together, the three hypotheses provide a partial but coherent explanation for the negative association between regulatory scope and DDS trade in Africa. The implementation-gap results show that regulatory scope is associated with more trade only conditionally on government effectiveness. The estimated switch point is higher for African importers (about 0.81) than for non-African importers (about 0.46), but the difference rests on imprecisely estimated Africa interactions and should be read as indicative. The complementarity analysis establishes that regulation works alongside electricity, education and broadband globally, but does not identify which of these complements is responsible for the weaker African performance. The measurement hypothesis receives the least support: the negative Africa effect recurs across ITU clusters, concentrating in the Regulatory Regime component that is most effective elsewhere, and the same paradoxical positive association appears in the OECD DSTRI, a measure constructed independently of the ITU Tracker. The weight of evidence therefore points to a misalignment between formal regulatory frameworks and the market conditions required for them to deliver trade-enhancing outcomes in the African context, rather than to the way those frameworks are measured.

4 A Model of Connectivity Supply and Demand

Section 3 identified two features of the relationship between connectivity and digitally deliverable services (DDS) trade that warrant further investigation. First, fixed broadband has a stronger association with DDS trade than mobile broadband, particularly on the export side. Yet fixed broadband remains scarce in many African economies. Second, telecommunications regulation is positively associated with DDS trade globally, but this relationship is weaker or negative in the African estimates. The gravity analysis also suggests that the relationship between regulation

and trade depends on complementary conditions, including electricity access, education and implementation capacity.

This section examines two possible reasons why expanding connectivity may be particularly difficult for fixed broadband. The first concerns the supply of connectivity: the cost of extending a network to each household depends on the number of potential customers it can serve and the conditions under which operators invest. The second concerns demand: even when households and firms are willing to subscribe, they cannot do so unless a network reaches them. These constraints have different implications for policy. Measures that make subscriptions more affordable may increase adoption where networks are already available, but may have limited effects where the main constraint is the absence of infrastructure.

The section develops a simple framework around these two constraints and examines whether the data are consistent with its predictions. The results provide evidence that fixed and mobile adoption respond differently to price. They also show that fixed-broadband prices are lower where subscriber density is higher. By contrast, the evidence for a regulatory-capacity threshold is inconclusive, and the data do not allow us to identify the operators' network investment decisions directly. These distinctions are important when drawing policy conclusions.

4.1 The theoretical framework

The framework considers fixed and mobile broadband separately. Its central distinction is between the number of households that would like to subscribe at a given price and the number that can actually obtain a connection. Consider a country c in year t; we suppress subscripts where no ambiguity arises. There are two technologies, $\tau \in \{F, M\}$ for fixed and mobile broadband.

Users: affordability and network availability

Suppose households' willingness to subscribe depends on the price of broadband and on factors such as income, digital skills and reliable electricity. These factors affect the value that households can obtain from an internet connection. Let $D_\tau(p_\tau;\, \mathbf{x})$ be the share of households that would subscribe to technology τ at price p_τ if a network were available to them, where $\mathbf{x}$ collects the determinants of willingness to pay. These are the complements documented in Section 3: a connection is worth little to a household that cannot afford a device, operate one, or charge one, and demand is increasing in each of them and decreasing in price. Write the price elasticity of demand as

$$\varepsilon_\tau \;\equiv\; -\frac{\partial \ln D_\tau}{\partial \ln p_\tau} \;>\; 0. \tag{6}$$

However, willingness to subscribe does not guarantee access. A household can only subscribe if the network reaches its location. We therefore distinguish between potential demand and the share of households that can be served by the existing network:

$$n_\tau \;=\; \min\left\{ \underbrace{D_\tau(p_\tau;\, \mathbf{x})}_{\text{would subscribe}} \;,\; \underbrace{\kappa_\tau}_{\text{passed by a network}} \right\}. \tag{7}$$

This distinction gives rise to two possible constraints on adoption. In a *price-constrained market*, network coverage is sufficiently broad, but some households do not subscribe because the price is too high. Reducing the price can then increase adoption. In an *availability-constrained market*, the network does not reach all households that might be willing to subscribe. In this case, adoption is limited by coverage, and reducing the subscription price alone may have little effect on the number of connections.

The distinction may be particularly relevant when comparing fixed and mobile broadband. Mobile networks can serve many users from a single base station, whereas fixed broadband generally requires a physical connection to each premise. Fixed networks may therefore reach a smaller share of households, particularly where settlement is dispersed or infrastructure is costly to extend. Where this is the case, availability may be a more important constraint on fixed adoption than affordability.

Proposition 1 (Rationing regimes)**.** *Mobile adoption is expected to be more responsive to price where network coverage is relatively broad. Fixed adoption is expected to be less responsive to price where network availability is the more binding constraint, and more closely related to coverage.*

An important qualification concerns the interpretation of the price coefficient. If fixed adoption is constrained by network availability, a small estimated price coefficient does not mean that households are insensitive to price. It means that price is not the main factor determining the number of observed subscriptions. Households outside the network cannot subscribe, even if they would be willing to do so at a lower price. The estimated relationship between price and adoption therefore need not reveal the underlying demand elasticity (Fair & Jaffee, 1972; Maddala & Nelson, 1974).

The framework leads to three empirical expectations. First, fixed adoption should be less responsive to price than mobile adoption. Second, the mobile price response may weaken as income rises and demand approaches saturation. Third, network coverage should be more closely associated with fixed adoption if availability is a more important constraint for fixed networks. The empirical analysis examines these patterns jointly.

Operators: the cost of extending networks

The supply side provides a reason why network availability may differ between the two technologies. Operators face both the cost of serving existing subscribers and the cost of extending their networks to reach additional households. The latter can be substantial. Mobile operators can extend coverage through a base station that serves many users, while fixed operators generally need to connect individual premises. We capture this difference by assuming that the fixed cost of extending fixed networks is higher than that of extending mobile networks:

$$F_F \gg F_M. \tag{8}$$

The cost of reaching additional households also varies across locations. Settlement density, terrain, the reliability of the electricity grid and distance from international fibre infrastructure can all affect the cost of network deployment. Operators are therefore likely to connect relatively inexpensive locations first, with the cost of reaching additional households rising as coverage expands.

The model assumes that operators extend their networks while the expected revenue from an additional household is sufficient to cover the cost of connecting it. Let $\phi(\kappa;\, z)$ denote the relative cost of reaching the marginal household once a share κ is already passed, increasing in κ, with z collecting settlement density, terrain, grid reliability and distance to international fibre capacity. Let $a_\tau \in (0, 1]$ denote the take-up rate among passed households, so that $a_\tau = n_\tau/\kappa_\tau$ in the notation of (7). The operator extends coverage while the expected margin from a passed household covers the cost of reaching the next household:

$$\underbrace{(p_\tau - c_\tau)\, a_\tau}_{\text{expected margin per household passed}} \quad = \quad \underbrace{F_\tau\, \phi(\kappa_\tau;\, z)}_{\text{cost of passing the marginal household}} \quad , \tag{9}$$

This condition implies an equilibrium level of network coverage:

$$\kappa^*_\tau \;=\; \phi^{-1}\left[\frac{(p_\tau - c_\tau)\, a_\tau}{F_\tau}\right]. \tag{10}$$

The condition highlights three considerations relevant to network expansion. First, the higher fixed cost of extending fixed networks can help explain why fixed coverage remains limited even where mobile coverage is widespread. Second, the cost of extending networks depends on local conditions, including settlement patterns and electricity infrastructure. Third, the recovery of network costs depends on the size of the subscriber base, as a larger number of subscribers allows fixed costs to be spread across more customers.

These relationships motivate the variables used in the empirical analysis. Geography and grid conditions enter the coverage equation as cost shifters, while subscriber density enters the price equation to capture the possibility that a larger customer base reduces average costs. The model's investment condition is not, however, estimated directly. As discussed below, the available instruments do not allow us to identify the relationship between operators' expected margins and network expansion reliably.

Regulation: competition and implementation costs

Regulation may affect the market for connectivity through more than one channel. On the one hand, effective competition rules can limit market power, support access to essential infrastructure and reduce uncertainty for investors. On the other hand, regulatory requirements can impose costs on operators, including licensing obligations, universal-service contributions, quality-of-service requirements and reporting obligations.

The balance between these channels may depend on the capacity of public institutions to implement and enforce regulation. We distinguish between formal regulatory scope, measured by the ITU Regulatory Tracker, and the capacity to implement it, proxied by government effectiveness. The model represents effective regulation as:

$$\tilde{R} \;=\; \chi(K)\, R, \qquad \chi' > 0, \quad \chi(0) = 0, \tag{11}$$

where $\chi(K)$ is the share of formal regulatory scope that implementation capacity makes operative.

The first channel is the effect of regulation on market conduct. Effective competition policy may constrain markups, although the extent to which formal rules affect operators' behaviour depends

on implementation and enforcement. The model expresses this relationship using the standard price–cost margin condition:

$$\frac{p_\tau - c_\tau}{p_\tau} \;=\; \frac{\mu_\tau\Big(\tilde{R},\, N_\tau\Big)}{\varepsilon_\tau}, \qquad \frac{\partial \mu_\tau}{\partial \tilde{R}} < 0, \tag{12}$$

where μ_τ is the conduct parameter—the equilibrium markup. It equals one under monopoly pricing, $1/N_\tau$ under symmetric Cournot competition, and zero under marginal-cost pricing. N_τ is the number of operators introduced above, and ε_τ is the demand elasticity of (6). Stronger effective regulation compresses the markup, $\partial \mu_\tau / \partial \tilde{R} < 0$.

This condition is most directly relevant where prices and subscriptions are determined by the interaction of supply and demand. Where fixed adoption is instead constrained by network availability, prices may also reflect the willingness to pay of the marginal household reached by the network:

$$p_F \;=\; w(\kappa_F)\,, \qquad w' < 0, \tag{13}$$

where $w(\kappa)$ is the willingness to pay of the marginal passed household. The assumption that w is decreasing captures the idea that networks are generally extended from locations that are relatively attractive to serve toward locations that are progressively more costly or have lower valuations.

As coverage expands, operators may reach households with lower willingness to pay, which could be associated with lower prices. This provides one possible interpretation of the relationship between fixed-broadband prices and network coverage.

The second channel concerns the costs of complying with regulation. These costs may be more consequential in markets where subscriber numbers and operator revenues are relatively low. A regulatory requirement that is manageable in a large, established market may represent a greater burden in a small market with a limited customer base. This does not mean that competition rules are undesirable in smaller markets. It means that their design and implementation need to take account of market conditions and the capacity of regulatory institutions.

Combining these channels gives a possible relationship between regulatory scope and network coverage:

$$\frac{d \ln \kappa_\tau^*}{dR} \;=\; \eta_\tau \, \frac{d \ln m_\tau}{dR}, \qquad \eta_\tau \;\equiv\; \frac{\partial \ln \kappa_\tau}{\partial \ln m_\tau} \;=\; \frac{m_\tau}{\kappa_\tau^* \, \phi'(\kappa_\tau^*)} \;>\; 0, \tag{14}$$

$$\frac{d \ln \kappa_\tau}{dR} \;=\; \underbrace{\frac{\partial \ln \kappa_\tau}{\partial \tilde{R}} \, \chi(K)}_{\text{(+) competition, entry, certainty}} \;-\; \underbrace{\frac{\Psi'(R)}{\pi_\tau}}_{\text{(–) compliance burden}}, \tag{15}$$

where $m_\tau \equiv (p_\tau - c_\tau) a_\tau / F_\tau$ is the normalised operating margin, so that $\kappa_\tau^* = \phi^{-1}(m_\tau)$ from (10).

The framework therefore allows for two opposing effects. Regulation may support competition and investment, but compliance costs may also reduce operators' returns, particularly in markets with a small subscriber base. The balance between these effects could vary with implementation capacity and market conditions.

There is an important qualification to this theoretical argument. The positive effect of the competition channel on network coverage is not implied by the operator cost condition alone. Lower markups can reduce the return from serving an additional household. A positive effect on coverage would therefore require other benefits, such as easier market entry or greater certainty for investment, to outweigh this reduction in margins. The model uses this as a possible mechanism rather than a result that follows automatically from the equations. Whether the balance of effects changes with implementation capacity is an empirical question.

Proposition 2 (Regulatory threshold)**.** *The relationship between regulation and network outcomes may depend on implementation capacity and market conditions. If the benefits of effective competition and regulatory certainty outweigh compliance costs only in markets with sufficient institutional capacity or operator profitability, the association between regulatory scope and prices or coverage may differ across countries. The relevant conditions could also differ between fixed and mobile broadband.*

The framework translates this possibility into estimating equations for prices and coverage:

$$\ln p_\tau \;=\; \gamma_{0\tau} \;+\; (\gamma_{1\tau} + \gamma_{2\tau} K)\, R \;-\; \gamma_{3\tau} \ln n_\tau \;+\; \mathbf{v}'\boldsymbol{\gamma}_{4\tau} \;+\; u_\tau^P, \tag{P$_\tau$}$$

$$\ln \kappa_\tau \;=\; \delta_{0\tau} \;+\; (\delta_{1\tau} + \delta_{2\tau} K)\, R \;+\; \mathbf{z}'\boldsymbol{\delta}_{3\tau} \;+\; u_\tau^K, \tag{K$_\tau$}$$

with $\mathbf{v}$ collecting input costs and $\mathbf{z}$ the geography and grid shifters of (9). Proposition 2 maps into sign restrictions on the pricing equation (P$_\tau$) and the coverage equation (K$_\tau$):

$$\gamma_{1\tau} > 0, \quad \gamma_{2\tau} < 0, \quad \delta_{1\tau} < 0, \quad \delta_{2\tau} > 0. \tag{16}$$

with an implied capacity switch point $K_\tau^\dagger = -\gamma_{1\tau}/\gamma_{2\tau}$ and $K_F^\dagger > K_M^\dagger$. The term $-\gamma_{3\tau} \ln n_\tau$ captures the recovery of F_τ over a larger subscriber base and predicts $\gamma_{3\tau} > 0$.

The interaction between regulatory scope and implementation capacity allows the association between regulation and prices or coverage to vary with government effectiveness. The implied switch point indicates the level of the capacity measure at which the estimated relationship changes sign. Such a point is informative only if it falls within the observed range of the capacity variable and is estimated with sufficient precision. It should not be interpreted as a policy target or as a structural estimate of the capacity required for effective regulation.

The corresponding demand equation is

$$\ln n_\tau \;=\; \zeta_\tau \ln \kappa_\tau \;-\; \varepsilon_\tau \ln p_\tau \;+\; \mathbf{x}'\boldsymbol{\theta}_\tau \;+\; u_\tau^D, \tag{D$_\tau$}$$

This equation links adoption to prices, network availability and the complementary factors that affect the value of a connection. In a price-constrained market, the price coefficient captures the response of demand to price. In an availability-constrained market, the relationship is instead a reduced-form representation of adoption under a binding coverage constraint. The key empirical expectation remains that fixed and mobile adoption will respond differently to price if network availability is more restrictive for fixed broadband.

Taken together, the framework highlights why policies aimed at lowering subscription prices may not be sufficient to expand fixed-broadband access. Where network coverage is limited, the more important challenge may be to make network deployment viable. This requires attention not only to operators' costs and market size, but also to the infrastructure and institutional conditions in which they operate.

Electricity is relevant on both sides of the market. Reliable power makes internet access more useful to households and firms, while also affecting the cost and reliability of network operations. Income and digital skills can increase households' ability to use and pay for connectivity, while settlement density can affect the economics of extending networks. The framework therefore treats these factors as complementary conditions for digital connectivity rather than as isolated determinants of adoption.

4.2 Empirical strategy

We estimate the model using a country–year panel, with country and year fixed effects throughout. The estimates therefore rely on changes within countries over time. Five considerations shape the empirical strategy.

Measuring affordability. The broadband price baskets are expressed as a share of monthly GNI per capita. This captures the cost of broadband relative to average income, but it also means that a low value can reflect either a cheaper service or a higher-income country. We therefore control for income in specifications that include price and also report results using the price basket in absolute dollars.

Comparing fixed and mobile adoption. The main prediction concerns the difference between the two technologies: fixed adoption should be less responsive to price, and more closely related to coverage, if network availability is a more binding constraint. We test this by estimating the fixed and mobile adoption equations jointly. The specification allows the coefficients to differ by technology and estimates the fixed–mobile differences directly. This is preferable to comparing whether two separate coefficients are individually significant.

We also examine whether the mobile price response weakens as income rises. If demand approaches saturation at higher income levels, the relationship between price and adoption should become smaller in magnitude. Under the availability-constraint interpretation, the fixed price coefficient should remain relatively small across income levels.

Assessing the role of implementation capacity. We examine whether the relationship between regulation and prices or coverage varies with implementation capacity, proxied alternatively by government effectiveness and by the World Bank's regulatory quality indicator. A linear interaction provides a way to assess whether the association changes with institutional capacity, but it does not by itself establish a threshold. We therefore calculate the implied switch point and compare it with the observed range of the capacity variable. If the switch point lies outside that range, the estimates do not identify a change in sign within the countries in the sample.

Distinguishing price and coverage relationships. Price and network coverage are jointly determined, making it difficult to identify their separate effects. We report both relationships and use the corresponding mobile specification as a comparison. If the negative relationship between price and coverage also appears for mobile broadband, it cannot be interpreted as evidence specific to the proposed fixed-network pricing mechanism.

Addressing endogeneity. Prices, coverage and adoption may influence one another. We therefore instrument prices and coverage using cost and geographic variables: applied ICT goods tariffs, submarine-cable landing events and distance, and settlement density. Regulation may also

respond to market development. We instrument it using the leave-one-out average Tracker score of countries sharing an official language or legal origin, on the assumption that regulatory approaches can spread across these peer groups for reasons not directly related to an individual country's connectivity shocks.

The first-stage statistics are reported alongside the instrumented specifications. Several instruments are weak, which limits the strength of the conclusions that can be drawn from these estimates. We therefore place greater emphasis on results that are stable across specifications and are less dependent on the weaker instruments.

4.3 Results

The rationing regimes

Table 9 reports the stacked adoption system testing proposition 1. The mobile price coefficient is −0.156 (0.050), negative and significant at the one per cent level. The fixed–mobile difference is +0.144 (0.056), also significant, so the fixed price coefficient is −0.012 (0.032): precisely estimated and indistinguishable from zero. This is the pattern Proposition 1 describes. Mobile adoption responds to price; fixed adoption does not.

This is consistent with the interpretation that mobile adoption is more price-responsive, while fixed adoption is more constrained by network availability. It does not mean that fixed-broadband demand is inherently unresponsive to price. Rather, where networks do not reach households, price reductions cannot generate subscriptions from those households. The result is therefore about the constraint determining observed adoption, not about the underlying willingness to pay.

The pattern is not explained by the use of prices relative to income. When the price basket is measured in absolute dollars, the mobile price coefficient remains negative and significant, at −0.102 (0.039), while the fixed–mobile difference remains positive, although estimated less precisely. The results also suggest that mobile adoption becomes less responsive to price as income rises. The mobile price interaction with income is positive and significant, while the implied income gradient for fixed adoption is close to zero. This is consistent with mobile demand becoming less price-sensitive as income increases, while the fixed price relationship remains relatively flat.

The coverage estimates point in the same direction, but are less precise. The implied fixed coverage coefficient is 0.140, compared with 0.061 for mobile. However, the difference between the two is not statistically significant in the baseline specification. It becomes significant in some alternative specifications, but this evidence is not sufficiently consistent to treat the coverage difference as a separate confirmation of the availability-constraint hypothesis. The price difference is the more conclusive result.

The results for complementary factors also require some qualification. Electricity access is positively associated with adoption in the pooled estimates, with a coefficient of 2.348 (0.689). Income is also positive, while the estimates for secondary enrollment and DDS content per capita are not statistically significant. When the coefficients are allowed to differ between technologies, the estimated electricity association is much weaker for fixed than for mobile adoption. The ITU Regulatory Tracker, by contrast, remains positively associated with fixed adoption. These estimates suggest that the factors associated with household adoption need not operate in the same way for

Table 9: *Proposition 1: rationing regimes*

	(1) Baseline	(2) Absolute price	(3) Africa interacted	(4) Income interacted
Dependent variable: fixed and mobile broadband adoption, subscriptions per 100 inhabitants				
Coverage	0.061***	0.064***	0.067***	0.057***
	(0.022)	(0.022)	(0.025)	(0.021)
Own price (% GNI)	−0.156***		−0.165***	−0.030
	(0.050)		(0.061)	(0.050)
Other technology's price	−0.018	−0.023	−0.014	−0.026
	(0.038)	(0.040)	(0.041)	(0.034)
Own price (USD per month)		−0.102***		
		(0.039)		
Complements shifting willingness to pay				
Electricity access (share)	2.348***	2.561***	2.480***	1.758**
	(0.689)	(0.700)	(0.716)	(0.714)
Secondary enrolment (share)	0.223	0.268	0.235	0.144
	(0.358)	(0.358)	(0.357)	(0.359)
ln(GDP per capita)	0.173**	0.235***	0.168**	0.114
	(0.081)	(0.085)	(0.078)	(0.084)
DDS content per capita, $t-2$	0.008	0.011	0.000	0.006
	(0.185)	(0.183)	(0.188)	(0.180)
ITU Regulatory Tracker (0–1)	0.716*	0.726*	0.697*	0.715**
	(0.367)	(0.375)	(0.371)	(0.348)
Government effectiveness (0–1)	0.511*	0.576*	0.524*	0.404
	(0.288)	(0.294)	(0.289)	(0.275)
Interactions with the fixed-technology indicator				
Fixed × coverage	0.079	0.074	0.154**	0.086*
	(0.052)	(0.053)	(0.066)	(0.051)
Fixed × own price	0.144**		0.179***	0.008
	(0.056)		(0.067)	(0.062)
Fixed × own price (USD)		0.072		
		(0.045)		
Fixed × other price	0.008	0.017	−0.005	0.016
	(0.049)	(0.049)	(0.050)	(0.048)
Africa and income interactions				
Africa × own price			0.029	
			(0.113)	
Africa × fixed × own price			−0.083	
			(0.122)	
Own price × ln(GDP p.c.), centred				0.119***
				(0.034)
Fixed × own price × ln(GDP p.c.)				−0.126***
				(0.041)
Memorandum: implied coefficients for fixed broadband				
Fixed price coefficient	−0.012	−0.030	0.014	−0.022
Fixed coverage coefficient	0.140	0.138	0.221	0.143
Implied income gradient, fixed price				−0.007
Observations	1,968	1,968	1,968	1,968
Countries	146	146	146	146

Notes: Fixed and mobile adoption equations stacked over technology, with country-by-technology and year-by-technology effects and standard errors clustered by country in parentheses. DDS content enters as a two-year lag and is therefore predetermined. In column 1 the implied fixed price coefficient is −0.012 with a standard error of 0.032. Under availability rationing that coefficient is not an estimate of a demand elasticity, so the regression does not trace a demand curve. Income is centred at the estimation sample mean, so the price coefficients in column 4 are evaluated at mean income. Subscriptions, coverage, both prices and DDS content per capita enter as $\ln(1+x)$, so each coefficient gives the percentage change in one plus subscriptions associated with a one per cent change in one plus the regressor. This approximates an elasticity where the variables are large relative to one, as for coverage and mobile subscriptions, but not for fixed subscriptions, whose levels are close to zero; the remaining regressors enter in levels. Table 39 in Appendix E reports all four columns in full.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$.

the two technologies.

The difference between fixed and mobile price responses is not specific to Africa. The interaction between Africa, fixed technology and price is not statistically significant. The results therefore suggest that the availability constraint is a broader feature of markets where fixed coverage is incomplete, rather than a mechanism unique to African economies. Africa is particularly exposed to this constraint because fixed network penetration remains very low.

We also examine whether the relationship differs across the African price distribution. Although the estimated price slopes vary across quartiles, they do not follow the pattern expected if affordability were the main constraint: the lowest-price quartile does not have the strongest negative price response. No segment of the African fixed-broadband price distribution provides clear evidence that adoption responds to price. Within the African sample, the results are more consistent with adoption moving with network availability than with price.

For policy, the distinction is important. Affordability measures may help increase mobile adoption, for which the estimates show a clear price response. For fixed broadband, however, reducing subscription prices may not be sufficient where households and businesses are outside the network. In those settings, extending coverage and addressing the costs of network deployment deserve attention alongside affordability.

Regulation and implementation capacity

Table 10 examines whether the relationship between regulation and network prices or coverage varies with implementation capacity. The main regulatory coefficient in the fixed-price equation is positive and statistically significant: 3.020 (1.418). The interaction between regulation and government effectiveness is negative, as predicted by the model, but is imprecisely estimated. Replacing government effectiveness with the World Bank's regulatory quality measure produces a similar pattern.

These results suggest that broader regulatory scope is associated with higher fixed-broadband prices in the estimated specifications. They provide some indication that this association may be weaker where institutional capacity is higher, but they do not establish that implementation capacity reverses the relationship.

The implied switch points are 1.32 for government effectiveness and 1.09 for the World Bank's regulatory quality indicator, the two capacity proxies in columns 1 and 2 of Table 10. Both exceed the upper bound of the capacity indicators, which range from zero to one. The estimates therefore do not identify a level of implementation capacity at which the relationship between regulation and fixed-broadband prices becomes negative. Moreover, the switch points are ratios of coefficients, and the interaction terms are imprecisely estimated. They should not be interpreted as precise thresholds or policy targets.

The coverage equation provides no stronger evidence of a threshold. The regulatory coefficients are statistically insignificant and have signs opposite to those predicted by the model. Although the implied mobile switch point lies within the observed range, it is calculated from two insignificant coefficients and is not informative. The first-stage statistics are also weak, particularly for the coverage equation. The instrumented estimates must therefore be interpreted cautiously.

Table 10: *Proposition 2: regulation, capacity and the threshold*

	(1) Price, GovEff	(2) Price, RegQual	(3) Coverage (mobile)
Dependent variable: fixed-broadband price, % of monthly GNI per capita (columns 1–2); mobile population coverage (column 3)			
ITU Regulatory Tracker (0–1)	3.020**	3.516**	4.844
	(1.418)	(1.631)	(4.976)
Government effectiveness (0–1)	2.182		2.438
	(1.553)		(5.733)
ITU Tracker × Gov. effectiveness	−2.294		−6.020
	(1.910)		(6.859)
WGI Regulatory Quality (0–1)		2.537	
		(1.855)	
ITU Tracker × Regulatory quality		−3.214	
		(2.171)	
Fixed subscriptions per 100 (instrumented)	−0.970**	−0.934**	
	(0.430)	(0.423)	
Mobile price, % GNI (instrumented)			−2.451***
			(0.827)
ln(GDP per capita)	−0.854***	−0.848***	−0.959
	(0.217)	(0.208)	(0.931)
ln(Population density)	−0.739	−0.623	−5.107
	(0.980)	(0.941)	(3.491)
Electricity access (share)	−2.706***	−2.819***	−2.013
	(0.914)	(0.889)	(4.709)
Memorandum			
Implied density economies γ_3	0.970	0.934	
Implied switch point $K^\dagger$	1.32	1.09	0.81
Observations	629	629	620
Kleibergen–Paap first-stage F	4.28	4.31	1.78

Notes: Country and year effects throughout, standard errors clustered by country. The price equation predicts a positive main effect and a negative interaction, so that the marginal effect of regulation switches sign at $K^\dagger = -\gamma_1/\gamma_2$; the coverage equation predicts the reverse pair. Columns 1 and 2 use two capacity proxies. The coverage margin is estimated on mobile, where population coverage is genuinely observed, and it omits the operating margin for the identification reason set out in the text; its first stage is the same as that of column 2 of Table 41. The density term enters (P_τ) with a negative sign, so $\gamma_3 = 0.970$. Capacity is measured on the unit interval, so a switch point above one lies outside the observed range: on these estimates regulation raises fixed-broadband prices at every observed level of implementation capacity. Both switch points are ratios in which the denominator is imprecisely estimated and should not be read as point estimates. The post-cable indicator was collinear with the country effects in column 3 and is omitted. The first-stage statistics are well below conventional thresholds, so the instrumented coefficients are read as descriptive rather than as identifying causal magnitudes. The switch points in columns 1 and 2 lie above the upper bound of the capacity variable, so the interaction does not locate a threshold within the observed data.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The most defensible conclusion is consequently narrower than the theoretical proposition. Regulatory scope is positively associated with fixed-broadband prices in the estimated specifications, and the interaction with implementation capacity has the expected negative sign. But the interaction is too imprecisely estimated to establish a threshold, and the implied price switch points lie outside the observed range. The results do not show that stronger implementation capacity is sufficient to reverse the regulatory price association.

From a policy perspective, these results highlight the need to examine how regulatory obligations are designed and implemented in markets with limited scale, and whether their scope of regulations should be better aligned with local market conditions. Regulatory requirements need to be enforceable and supported by capable institutions. Their implementation should also take account of the size of the market, the costs faced by operators and the potential implications for network prices and expansion. The estimates identify a relationship worth investigating, but they do not establish which regulatory changes would reduce prices or increase coverage.

The network investment mechanism remains difficult to identify

The model also proposes that operators' decisions to extend networks depend on the expected return from connecting additional households. A larger subscriber base may help operators spread the fixed costs of network deployment, while geography and infrastructure conditions affect the cost of reaching new locations. The empirical analysis attempts to examine these relationships in Tables 41 and 42 in Appendix E.

The estimated relationship between the operating margin and coverage has the opposite sign to that predicted by the model. Using price as a proxy for the operating margin, the coefficient is negative and statistically significant, including when income is controlled for and when prices are measured in absolute dollars. The data therefore do not provide support for the predicted positive relationship between the operating margin and network expansion. Since marginal costs are unobserved and the instruments are weak, this result should not be interpreted as evidence that higher returns discourage investment.

A more consistent descriptive relationship is found between fixed prices and coverage: prices are lower where coverage is higher. This is compatible with the possibility that operators can serve a wider range of customers and spread network costs across a larger subscriber base as coverage expands. However, the same negative relationship appears in the mobile placebo specification. It is therefore not specific to the fixed-network pricing mechanism proposed by the model.

Taken together, these estimates do not allow us to distinguish reliably between the different mechanisms linking prices, coverage and investment. The relationship between fixed prices and coverage is informative, but it does not establish that expanding coverage causes prices to fall or that higher operator margins lead to greater network deployment. A stronger test would require data on operator costs, investment, market entry and network expansion, together with instruments that affect prices without directly affecting the cost of extending the network.

Summary

Table 11 compares the model's predictions with the empirical results. The evidence is strongest for the difference between fixed and mobile price responses: mobile adoption responds to price, while the fixed price coefficient is close to zero. The coverage difference is consistent with the model but less precisely estimated. The results also show that the relationship between regulation and fixed-broadband prices is positive in the estimated specifications, but do not establish the proposed implementation-capacity threshold. Finally, the operator investment condition cannot be identified with the available instruments.

Table 11: *Model predictions against the estimates*

Prediction	Predicted	Estimate (s.e.)	Verdict
Proposition 1: rationing regimes			
Mobile price coefficient < 0	$-$	-0.156 (0.050)	Supported
Fixed–mobile price gap > 0	$+$	0.144 (0.056)	Supported
Fixed price coefficient ≈ 0	0	-0.012 (0.032)	Supported
Fixed–mobile coverage gap > 0	$+$	0.079 (0.052)	Inconclusive
Mobile saturation: price $\times$ income > 0	$+$	0.119 (0.034)	Supported
Africa $\times$ fixed price ≈ 0	0	-0.083 (0.122)	Not Africa-specific
Cheapest African price quartile ≈ 0	0	0.044 (0.061)	Flat
Proposition 2: regulatory threshold			
$\gamma_1 > 0$ (regulation raises price)	$+$	3.020 (1.418)	Supported
$\gamma_2 < 0$ (capacity switches sign)	$-$	-2.294 (1.910)	Inconclusive
$\gamma_3 > 0$ (density economies)	$+$	0.970 (0.430)	Supported
$\delta_1 < 0$ (coverage equation)	$-$	4.844 (4.976)	Inconclusive
$\delta_2 > 0$ (coverage equation)	$+$	-6.020 (6.859)	Inconclusive
Switch point $K_F^\dagger$	—	1.32	Above observed range
Switch point $K_M^\dagger$	—	0.81	Inconclusive
Supply block			
Coverage rises in the margin	$+$	-2.451 (0.827)	Contradicted
Tariff-only first-stage F	—	0.48	No power
Pricing bound: price falls in coverage	$-$	-0.955 (0.209)	Supported
Mobile placebo on the pricing bound	0	-0.572 (0.126)	Placebo fails

Notes: "Predicted" gives the sign the model requires; 0 denotes a prediction of no effect. Verdicts use a ten per cent threshold. Switch points are ratios of estimated coefficients and carry no standard error; the verdict records whether they fall inside the unit interval on which capacity is measured. Sources: Tables 9, 10, 40, 41 and 42.

The findings point to a distinction between policies that make existing connections more affordable and policies that extend networks to places that are not yet served. The former may be relevant for mobile adoption, where the estimated price response is clear. For fixed broadband, the results suggest that availability is a more important constraint. This places greater emphasis on the conditions that support network deployment, including subscriber density, reliable electricity and the costs of reaching additional households.

The regulatory results should be interpreted with caution. They show a positive association between the scope of regulation and fixed-broadband prices across the estimated specifications, but they do not establish a causal effect or show that this relationship changes beyond a particular level of government effectiveness. The policy implication is therefore not to reduce regulatory ambition, but to consider how regulatory frameworks can be designed and implemented effectively in markets with limited scale and institutional capacity.

Overall, the analysis suggests that expanding fixed broadband requires more than measures to reduce subscription prices. It also requires attention to network availability and to the infrastructure and market conditions that make expansion viable. These considerations complement the gravity results in Section 3: if fixed connectivity is particularly relevant to DDS exports, then addressing the constraints on fixed-network deployment is an important part of a broader strategy to support participation in digital services trade.

5 Conclusion

Digitally delivered services are one of the fastest-growing parts of African trade, and they offer a route to export diversification that depends less on transport infrastructure and border procedures than goods trade does. Yet Africa still supplies less than one per cent of world exports of these services (World Bank & WTO, 2023, 2025). This paper asks when digital connectivity translates into trade in digitally deliverable services (DDS), with a particular focus on Africa, where fixed-broadband adoption remains persistently low. The analysis combines structural gravity estimates of DDS trade with an examination of broadband adoption, prices and regulatory conditions. Together, the results suggest that connectivity and regulation matter, but their contribution depends on the infrastructure, market conditions and institutional capacity that support them.

Four findings stand out. First, fixed broadband is more strongly associated with DDS trade than mobile broadband in both datasets, particularly on the exporter side. This pattern is consistent with the greater capacity, stability and reliability required to produce and export digitally deliverable services. Fixed networks also provide backhaul infrastructure for mobile networks, so the two technologies should be viewed as complements rather than substitutes. The implication is that expanding basic mobile access remains important, but it cannot fully replace the fixed infrastructure needed to support more data-intensive economic activity. Because the association is strongest on the exporter side, it is the finding most directly relevant to diversification: it suggests that the capacity to supply DDS abroad, and not only to use digital services, depends on fixed infrastructure.

Second, the constraints on broadband adoption differ between fixed and mobile technologies. Mobile adoption responds more clearly to price, whereas the estimated price relationship for fixed broadband is weak. Fixed adoption is more closely associated with network availability, a pattern consistent with the availability-rationing mechanism developed in the theoretical model. Where a network does not reach a household, a lower subscription price cannot by itself make a fixed connection possible. This distinction matters for policy: affordability measures may have a more direct effect on mobile adoption, while expanding fixed-broadband coverage requires attention to network deployment as well as prices. The results do not establish that affordability is unimportant for fixed broadband; rather, they suggest that price reductions alone may have limited effects where availability remains a binding constraint.

Third, the relationship between the scope of regulations and DDS trade differs between African and non-African economies. Regulatory scope is positively associated with trade in the global estimates, but this relationship is weaker, and in some specifications negative, for African economies. The results suggest that formal regulatory frameworks are more likely to be associated with stronger trade outcomes when accompanied by effective implementation and complementary

conditions. The positive interactions with government effectiveness, electricity access, education and broadband penetration reinforce this interpretation. As an illustration of these differences, the estimated switch points place the average African economy below the thresholds for government effectiveness and electricity access, consistent with the weaker relationship observed for African economies.[9]

Fourth, electricity, education and regulation are not independent policy levers. The gravity estimates show positive interactions between regulatory scope and these complementary factors, across both datasets. This suggests that the contribution of regulation to DDS trade depends partly on the wider conditions in which it operates. Electricity enables households to use digital devices and allows networks to function reliably; education and digital skills help people and firms make productive use of connectivity; and broadband infrastructure provides the capacity needed to participate in digitally delivered markets. These relationships work in both directions: complementary infrastructure and human capital can strengthen the contribution of regulation, while effective regulation can help these investments translate into better connectivity and trade outcomes. The estimated switch points are useful for illustrating this complementarity, but they should not be interpreted as universal policy targets.

These findings help clarify the conditions underlying Africa's limited participation in digitally delivered services exports. WTO simulations project that wider use of digital technologies could increase African exports of these services by about USD74 billion between 2023 and 2040, but this projection assumes improvements in digital connectivity and reductions in trade costs (World Bank & WTO, 2023). Our results point to some of the conditions needed to support these improvements: fixed as well as mobile infrastructure, regulation that can be implemented effectively, reliable electricity and relevant skills. The concentration of exports in three economies is consistent with these conditions being more fully developed in a limited number of markets, although we do not test this explanation directly. Nor do the estimates quantify the export gains from any particular investment. Rather, they identify conditions associated with stronger participation in DDS trade.

The policy implications follow from the differences across technologies and markets. For mobile broadband, affordability and effective competition remain important. For fixed broadband, policy should place greater emphasis on extending network availability, while continuing to address affordability. This requires conditions that support investment in backbone and last-mile infrastructure, particularly in areas where coverage remains limited. Regulatory frameworks also need to be matched by the capacity to implement them, including clear responsibilities, adequate administrative resources, supporting rules and procedures, and effective monitoring and enforcement. These efforts should be pursued alongside investments in reliable electricity and education, which help ensure that connectivity can be used productively. Although the evidence does not establish a universal sequence for these interventions, it suggests that infrastructure, institutional capacity and human capital are complementary conditions for translating digital policy reforms into trade gains.

These findings are relevant to ongoing regional initiatives, including the AfCFTA Protocol on Digital Trade, which aims to support a more integrated digital market across Africa (African Union, 2024). While this paper does not assess the Protocol's broader provisions on issues such as data governance and trade facilitation, it highlights some of the infrastructure and institutional

[9]The average African economy in our data has government effectiveness at the 27th percentile of the world distribution and electricity access of 45 per cent, well below the roughly 0.5 and 0.8 at which the estimated relationship between regulation and imports turns positive.

conditions needed for its implementation: networks that reach firms and households, reliable electricity, and regulators with the capacity to apply new rules. Since these conditions vary widely across African economies, harmonised rules alone may produce uneven results. Regional cooperation, capacity building and technical assistance, including through the joint World Bank–WTO Digital Trade for Africa project (World Bank & WTO, 2025), can help address these differences and support wider participation in digital trade.

Several limitations qualify these conclusions. First, measures of broadband availability and quality remain incomplete, particularly for fixed networks, and household internet access is not a direct measure of fixed-network coverage. The African sample in ITPD-E is also relatively limited, while gaps in bilateral trade data are filled with estimates in the BaTiS database. Second, the connectivity analysis faces additional challenges in separating the effects of regulation on prices, operator incentives, and network coverage. In particular, the first-stage statistics are weak in the instrumental-variable specifications, and the estimated regulatory-capacity threshold is not supported by a statistically precise sign reversal within the observed range. The proposed relationship between operating margins and network expansion is also not established by the data. Finally, the ITU Regulatory Tracker captures telecommunications regulation rather than the broader set of policies governing digital trade. We also tested the Digital Services Trade Restrictiveness Index (DSTRI), which is designed to capture barriers to digital trade, but its inclusion did not yield the expected results. This limits the extent to which the analysis can speak to the effects of the broader digital trade policy environment.

These limitations point to priorities for further research. Better data on fixed-network coverage, investment, operator costs and regulatory implementation would help distinguish constraints on network supply from those affecting household demand. Firm-level evidence could clarify how connectivity quality and reliability shape participation in DDS trade. More credible sources of exogenous variation in infrastructure deployment and regulatory change would also help establish whether the relationships identified here are causal.

The broader message is that digital connectivity does not automatically translate into economic participation. Fixed infrastructure, affordable access, effective regulation, electricity and skills are complementary conditions for developing digitally deliverable services trade. For African economies, the challenge is therefore not simply to expand connectivity or adopt more advanced regulatory frameworks, but to build the infrastructure and institutional capacity needed to make these investments and policies work together.

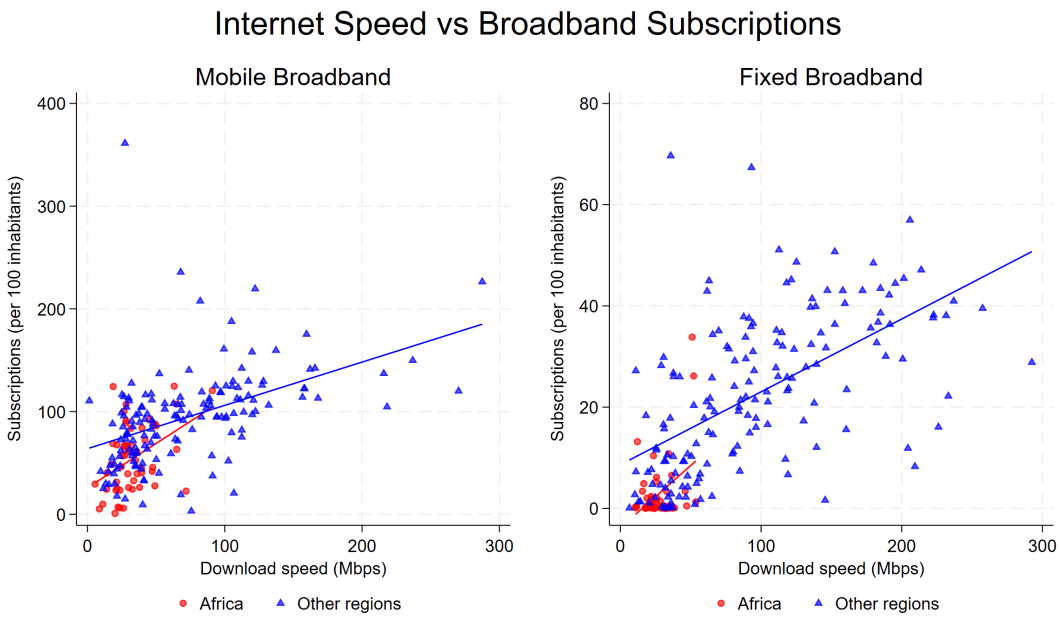
A Additional figures and tables for stylized facts

This appendix presents supplementary figures supporting the discussion of the stylized facts.

Internet speed and latency reflect quality of connectivity

Figure 7 presents scatterplots of broadband subscriptions against download speeds.

Figure 7: *Higher internet speeds associated with greater broadband adoption*



Note: The figure plots broadband subscriptions per 100 inhabitants against median download speeds (Mbps), averaged over 2020–2025. Left panel: mobile broadband; right panel: fixed broadband. African countries in red circles; other regions in blue triangles. Download speeds are median values aggregated from Ookla's quarterly tile-level open data. Fitted lines use OLS regression by region; the African line spans only the narrow range of speeds African countries record. Data sources: ITU (subscriptions); Ookla (download speeds).

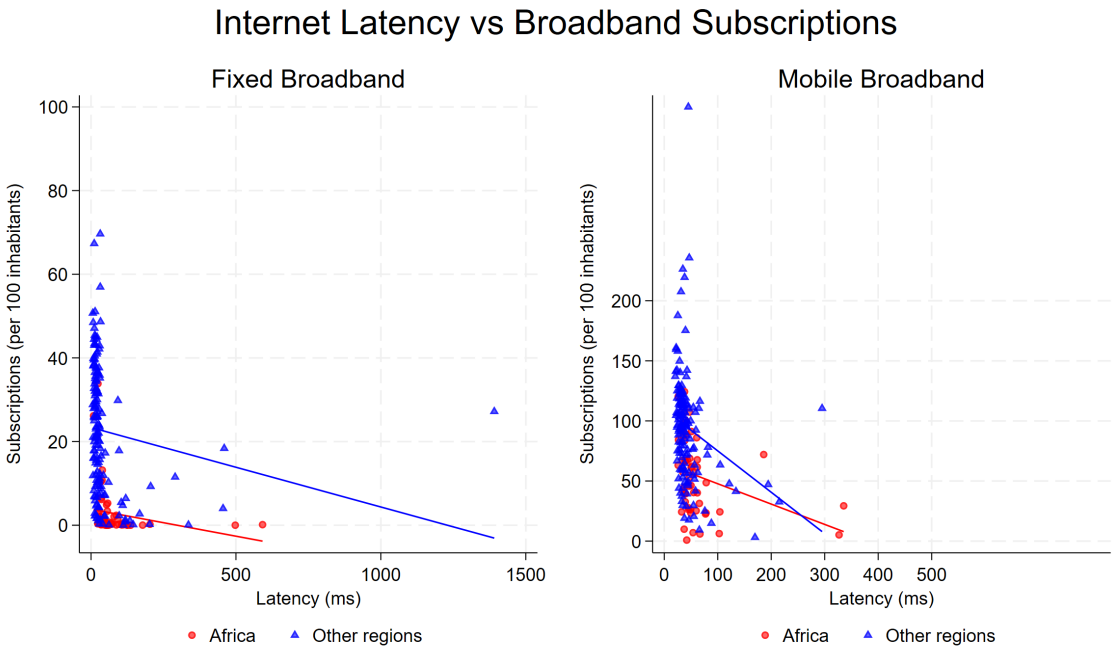
For fixed broadband, the patterns reveal a positive association between internet speed and adoption. Non-African countries exhibit download speeds up to 300 Mbps. African countries cluster tightly at low speeds (mostly below 60 Mbps) and low subscription rates (mostly below 10 per 100 inhabitants), and most lie below the fitted line for other regions, so that at comparable speeds African countries tend to have fewer subscriptions.

For mobile broadband, the association is also positive. African observations again sit at the low end of the speed distribution, but the vertical gap relative to the fitted line for other regions is smaller than for fixed broadband. This is consistent with speed mattering less for mobile adoption, plausibly because mobile networks are used for less bandwidth-intensive applications (voice, SMS, mobile money).

These correlations between internet quality (higher speed, and lower latency as shown in Figure 8) and broadband adoption motivate our gravity analysis in Section 3, which examines whether connectivity quality affects DDS trade.

Figure 8 plots broadband subscriptions per 100 inhabitants against latency for fixed and mobile broadband. Both panels display a negative relationship: lower latency (faster response times) is associated with higher broadband adoption. African economies (red) sit disproportionately in the high-latency, low-subscription region of both panels, indicating that the region tends to combine slower network responsiveness with thinner adoption.

Figure 8: *Lower latency (faster response times) associated with greater broadband adoption*



Note: The figure plots broadband subscriptions per 100 inhabitants against latency in milliseconds (ms), averaged 2020–2025. Lower latency indicates faster response times and better quality. Left panel: fixed broadband; right panel: mobile broadband. African countries in red; other regions in blue. Latency measured as round-trip time aggregated from Ookla's quarterly tile-level data. Data sources: ITU (subscriptions), Ookla (latency).

Content Availability Associated with Broadband Demand

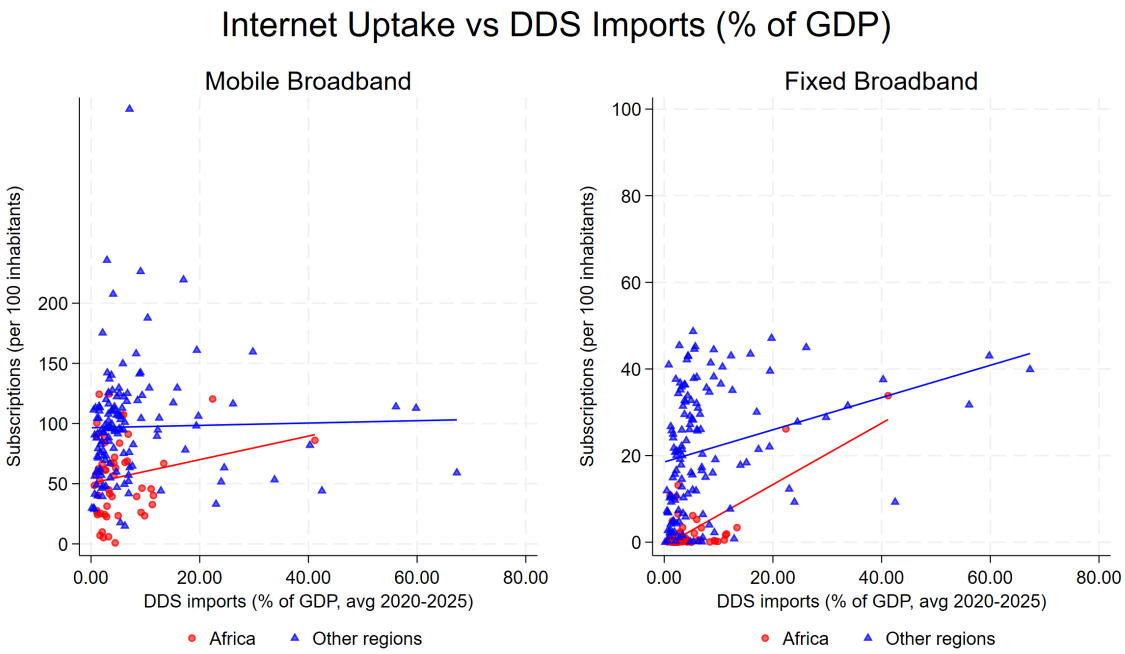
We use trade in DDS as a proxy for the availability of such content and services.[10] Under this hypothesis, higher DDS imports indicate richer content ecosystems that could, in principle, stimulate connectivity demand through indirect network effects and knowledge spillovers. At the same time, the correlation we document below is also consistent with the reverse channel, in which higher connectivity enables more DDS trade, or with both operating simultaneously.

Figure 9 plots broadband subscriptions against DDS imports as a share of GDP, using averages over 2020–2025.

For mobile broadband, the fitted line for non-African countries is nearly flat: among non-African countries, additional DDS imports show little association with further mobile growth, likely a saturation effect. Most African countries cluster at low DDS intensities (below 10% of GDP) with

[10]DDS encompasses: insurance and pension services; financial services; charges for intellectual property n.i.e.; telecommunications, computer, and information services; other business services; and audiovisual/recreational services, following BPM6/EBOPS 2010 classifications (IMF-OECD-UNCTAD-WTO, 2023).

Figure 9: *Content availability is associated with fixed broadband adoption*



Note: The figure plots broadband subscriptions per 100 inhabitants against digitally deliverable services (DDS) imports as a percentage of GDP, averaged over 2020–2025. Data sources: ITU (subscriptions); WTO–OECD BaTiS dataset (DDS imports); World Bank (GDP).

subscription rates between 20 and 80 per 100 inhabitants. Africa's fitted line exhibits a positive slope: moving from 0% to 10% DDS imports corresponds to an increase from approximately 50 to 60 mobile subscriptions.

For fixed broadband, the relationship is much stronger. Non-African countries show a positive relationship, suggesting higher DDS intensities are associated with substantially higher fixed subscriptions. Africa's fitted line has an even steeper positive slope but remains well below those of other regions. Even African countries with moderate DDS intensities (5–10% of GDP) achieve only 2–4 fixed subscriptions per 100, whereas the fitted line for non-African countries at similar DDS intensities lies at around 20 subscriptions. These patterns indicate complementarity between content and connectivity, particularly for fixed broadband.

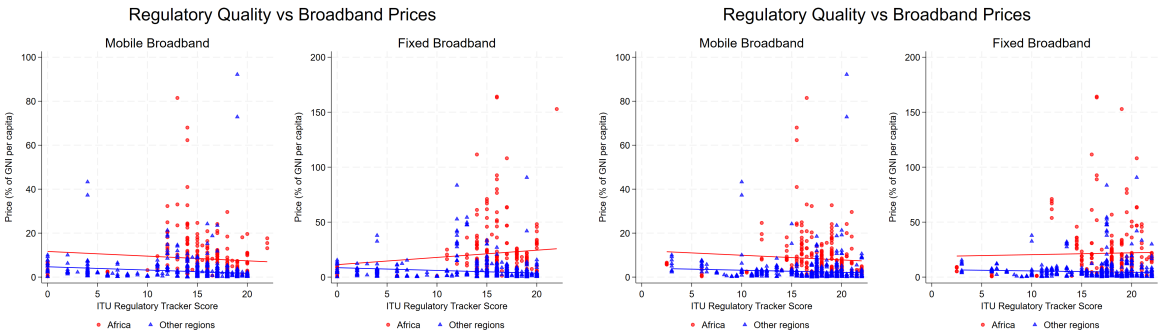
Figure 10 decomposes the ITU Regulatory Tracker into its four constituent clusters and plots each against broadband prices, revealing broadly similar relationships across clusters. In particular, the counterintuitive positive association between regulatory quality and fixed broadband prices in Africa noted in Stylized Fact 4 recurs across all four clusters rather than being driven by any single regulatory dimension, suggesting that the pattern is a feature of the regulatory environment as a whole rather than of one specific component.

Figure 11 traces broadband adoption in the years surrounding each country's attainment of Generation 4 (G4) regulatory status, defined as an ITU Tracker score of 85 or above. At the point of adoption (time zero), African countries averaged about three fixed subscriptions per 100 inhabitants against about 22 in other regions, a gap that does not close in the years that follow and is precisely estimated. The mobile gap is smaller (about 52 against 62 at adoption) and

Figure 10: *ITU regulatory tracker clusters and broadband prices: Africa versus other regions*

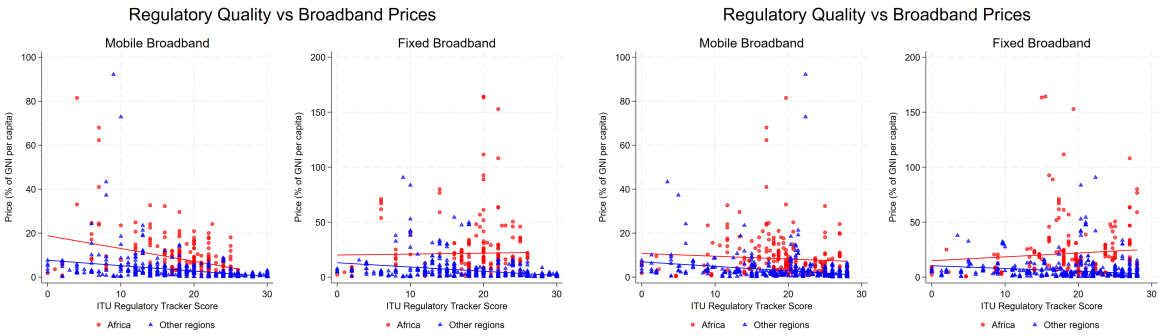
(a) Cluster 1: Regulatory Authority

(b) Cluster 2: Regulatory Mandate



(c) Cluster 3: Regulatory Regime

(d) Cluster 4: Competition Framework

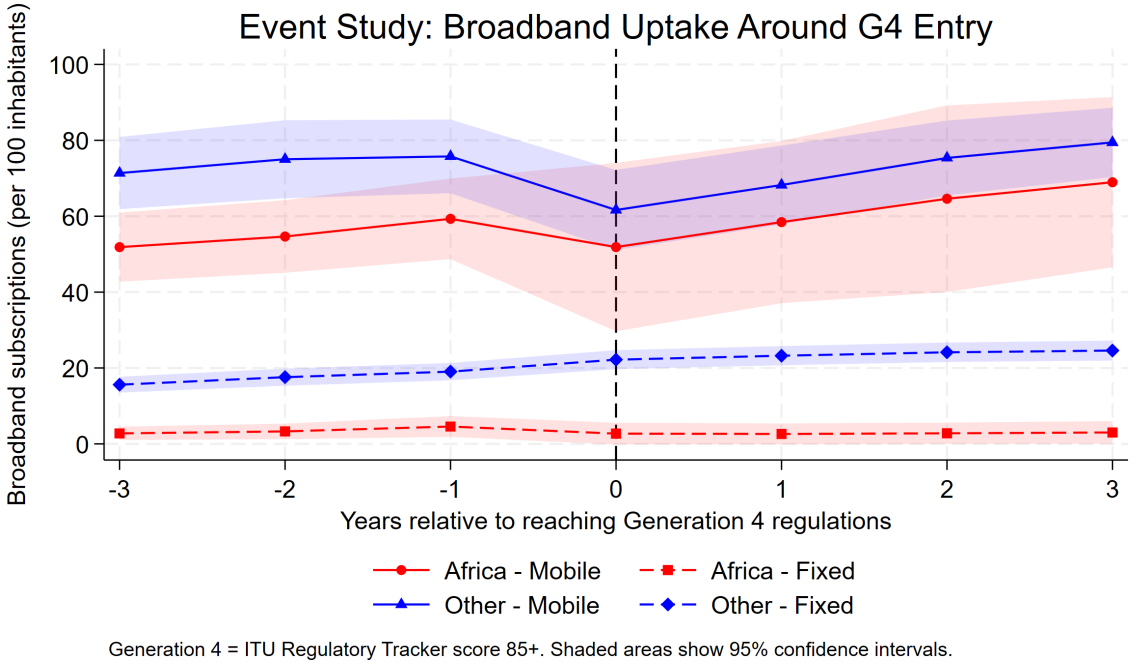


Note: The figure decomposes the ITU ICT Regulatory Tracker into its four constituent clusters and plots each cluster score, in the Tracker's original points (Clusters 1–4 have maximum scores of 20, 22, 30 and 28 respectively), against broadband prices as a percentage of monthly GNI per capita, 2019–2022. Each panel shows results for one cluster. Within each panel, the left side shows mobile broadband (2GB data plan) and the right side fixed broadband (5GB basket). African countries are shown in red; other regions in blue. Fitted lines use OLS regression by region. Data sources: ITU ICT Regulatory Tracker and ITU World Telecommunication/ICT Indicators Database. See Section 2 for a detailed description of the cluster definitions.

the confidence intervals overlap throughout, so it is indicative only. The fixed-broadband pattern corroborates the stylized-fact evidence in the main text that African economies tend to adopt advanced regulatory frameworks at markedly lower levels of market development than their peers, consistent with best-practice rules being introduced before the market density needed to make them effective has emerged.

Finally, Figure 12 examines digital skills. Each panel plots the actual share of the population possessing a given skill—sending an email with attached files in panel (a), and writing a computer program in panel (b)—against the share predicted by per capita income alone, where the prediction comes from a bivariate regression of the skill share on log GDP per capita. Each panel shows other regions on the left and Africa on the right; points below the diagonal on which actual equals predicted denote skill levels that fall short of what a country's income would predict. African economies occupy the bottom of the predicted range in both panels, reflecting their lower incomes, and a large share of them record actual skill levels below their predicted values, pointing to a digital-skills shortfall that income differences alone do not explain. This shortfall in complementary human capital echoes the paper's broader theme that the trade and adoption returns to connectivity and regulation depend on enabling factors—here, the skills required to produce and consume

Figure 11: *African countries adopted G4 regulations at lower broadband density than other regions*

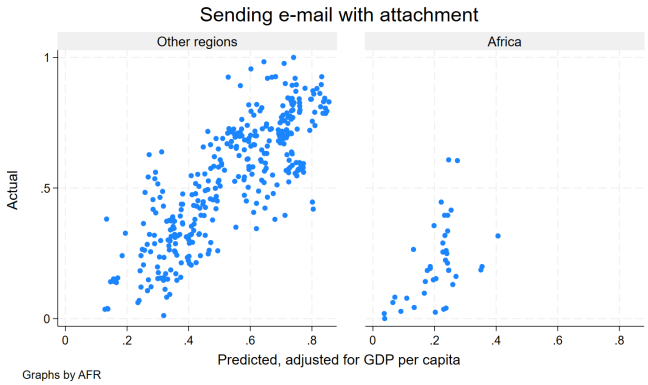


Note: The figure plots average broadband subscriptions per 100 inhabitants in years surrounding adoption of Generation 4 (G4) regulatory status (ITU Tracker score 85+). Time zero (vertical dashed line) represents the year of G4 adoption. Solid lines show mobile broadband (Africa in red, other regions in blue); dashed lines show fixed broadband. Shaded areas show 95% confidence intervals. The sample includes countries that achieved G4 status between 2007 and 2022. Data source: ITU.

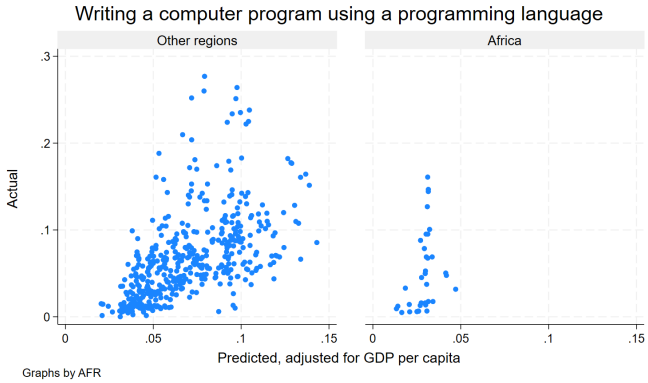
digitally deliverable services—that remain relatively scarce in the region.

Figure 12: *Computer skills: Africa versus other regions*

(a) Sending email with attached files



(b) Writing a computer program using a programming language



Note: The figures plot the actual share of the population possessing the specified computer skills (from ITU survey data) against a predicted share adjusted for GDP per capita. The predicted values are obtained from bivariate regressions of skill shares on log GDP per capita. Left sub-panel: other regions; right sub-panel: Africa. Points above the diagonal on which actual equals predicted indicate stronger-than-expected skills given income; points below indicate weaker-than-expected skills. Panel (a) shows the percentage of individuals who can send emails with attached files; panel (b) shows the percentage who can write computer programs using a programming language. Data source: ITU ICT Indicator surveys.

B African economies in the ITPD-E estimation sample

Table 12: *African economies in the ITPD-E estimation sample*

Economy	ISO	Years in sample	*N* years	Observations
Algeria	DZA	2006–2021	16	157
Angola	AGO	2006–2021	16	190
Benin	BEN	2006–2009, 2012, 2018–2021	9	54
Botswana	BWA	2005–2023	19	211
Burkina Faso	BFA	2005–2022	18	125
Cabo Verde	CPV	2006–2023	18	105
Cameroon	CMR	2006–2021	16	92
Central African Republic	CAF	2015, 2018–2019, 2021	4	12
Chad	TCD	2009, 2019–2021	4	8
Comoros	COM	2007–2009, 2017	4	8
Côte d'Ivoire	CIV	2006–2009, 2013–2021	13	115
Democratic Republic of the Congo	COD	2014, 2017–2021	6	40
Djibouti	DJI	2008–2009, 2019–2021	5	15
Egypt	EGY	2002–2023	22	3,070
Equatorial Guinea	GNQ	2005–2009, 2012, 2018–2021	10	78
Eritrea	ERI	2008–2009, 2021	3	8
Eswatini	SWZ	2008–2022	15	249
Ethiopia	ETH	2005–2009, 2014, 2016–2017, 2019–2021	11	90
Gabon	GAB	2005–2009, 2015, 2019–2021	9	81
Gambia	GMB	2007–2009, 2012–2022	14	120
Ghana	GHA	2005–2021	17	204
Guinea	GIN	2010–2021	12	60
Guinea-Bissau	GNB	2012, 2019–2021	4	14
Kenya	KEN	2005–2021	17	365
Lesotho	LSO	2007–2022	16	84
Liberia	LBR	2008–2017, 2019–2022	14	170
Libya	LBY	2008–2014, 2016–2017, 2019–2021	12	141
Madagascar	MDG	2006–2009, 2013, 2016–2021	11	56
Malawi	MWI	2007–2008, 2019–2021	5	20
Mali	MLI	2006–2009, 2012–2013, 2016, 2018–2021	11	70
Mauritania	MRT	2006–2009, 2011–2013, 2017–2021	12	64
Mauritius	MUS	2006–2023	18	412
Morocco	MAR	2002–2023	22	2,882
Mozambique	MOZ	2006–2023	18	167
Namibia	NAM	2006–2008, 2012–2023	15	142
Niger	NER	2004–2017, 2019–2021	17	104
Nigeria	NGA	2005, 2007–2010, 2012–2023	17	2,299
Republic of the Congo	COG	2009–2011, 2013–2014, 2021	6	44
Rwanda	RWA	2005–2009, 2012, 2014–2021	14	81
São Tomé and Príncipe	STP	2007–2009, 2017, 2019–2021	7	14
Senegal	SEN	2006–2009, 2013–2021	13	165
Seychelles	SYC	2004–2021	18	286
Sierra Leone	SLE	2019–2021	3	18
Somalia	SOM	2012–2013, 2017, 2019–2021	6	24
South Africa	ZAF	2002–2023	22	4,127
Sudan	SDN	2006–2008, 2010–2013	7	30
Tanzania	TZA	2006–2009, 2013–2021	13	123
Togo	TGO	2007–2009, 2012, 2019–2021	7	41
Tunisia	TUN	2006–2021	16	217
Uganda	UGA	2006–2016, 2019–2021	14	203
Zambia	ZMB	2006–2022	17	176
Zimbabwe	ZWE	2006–2009, 2014–2021	12	82
Total: 52 economies			**12.4**	**17,713**

Notes: The table lists the African economies appearing as importers in the ITPD-E estimation sample, defined as the estimation sample of the baseline specification. Years in sample reports every year in which the economy appears; *N* years is the count of those years, ranging from 3 to 22 with a mean of 12.4. Observations counts economy-partner-industry-year cells. Economies are listed in alphabetical order. Egypt, Morocco, Nigeria and South Africa together account for 12,378 of the 17,713 observations, or 70 per cent of the recorded African total.

Composition of the BaTiS sample

BaTiS reports a balanced matrix, and the release records for every cell the method by which its balanced value was obtained. Table 13 summarises that record for the digitally deliverable services matrix and compares the cells that are modelled with those that are not. It is the basis for the robustness analysis in Appendix D, which re-estimates the BaTiS specifications with every modelled cell removed.

Two readings matter. The share of the matrix that is modelled is large, so the restriction is costly in precision. But the modelled and reported cells are close to balanced on the characteristics that enter the regressions: every normalised difference is well inside the conventional 0.25 threshold, and the share of cells modelled is flat across quartiles of exporter income. The restriction therefore shrinks the sample without visibly changing its composition, which is what makes the comparison in Appendix D informative.

Table 13: *Which BaTiS observations are modelled?*

	Reported	Modelled	Norm. diff.
Panel A: share of the DDS matrix			
Observations	1,333,010	3,467,050	
Share of cells (%)	27.8	72.2	
Share of traded value (%)	67.1	32.9	
Panel B: cells by BaTiS code family (%)			
Reported (`R*`)		4.5	
Estimated (`E*`)		6.2	
Modelled (`M*`)		72.2	
Neither reported nor modelled (`W*`)		17.1	
Panel C: exporter characteristics, cell means			
GDP per capita (USD)	14,582	14,207	−0.019
Fixed broadband per 100	12.45	12.23	−0.016
Mobile broadband per 100	51.63	55.62	0.082
Electricity access (%)	81.10	81.70	0.021
Secondary enrolment (%)	86.65	84.52	−0.077
ITU Regulatory Tracker (0–100)	63.29	65.40	0.088
Panel D: share of cells modelled (%)			
Exporter income quartile 1 (poorest)		70.8	
Exporter income quartile 2		79.2	
Exporter income quartile 3		70.1	
Exporter income quartile 4 (richest)		67.8	
Pairs involving an African economy		75.1	
All other pairs		69.5	

Notes: Observations are reporter–partner–year–item cells of the BaTiS digitally deliverable services matrix, before any estimation sample restriction. A cell is classified as modelled where its BaTiS method code begins with `M`; the codes are strings such as `M2.1` and `E8.2`, so the classification is on the leading character. Exporter characteristics are cell means, so an economy contributes in proportion to its number of partner–year–item cells rather than once. The normalised difference is $(\bar{x}_1 - \bar{x}_0)/\sqrt{(s_1^2 + s_0^2)/2}$; values above roughly 0.25 in absolute value indicate imbalance large enough that linear adjustment is unreliable. Panels B and D report shares of all cells, with quartiles formed on exporter GDP per capita.

C Full ITPD-E and BaTiS regression tables

This appendix reports the complete coefficient estimates underlying the results summarised in Section 3, for both the ITPD-E and BaTiS specifications. The ITPD-E specification includes internal trade and uses exporter-year, importer-year, country-pair, and sector fixed effects, so that a country-specific variable interacted with the international-border dummy ($\times$ INTL) is identified relative to that country's domestic sales; under this structure the exporter- and importer-side effects of a country variable cannot be separated, so the variable is entered on the importer side. The BaTiS specification contains only international trade and instead combines country-pair and sector fixed effects with a Baier & Bergstrand (2009) approximation of the multilateral resistance terms, which permits separate exporter- and importer-side effects to be identified. Time-invariant exporter and importer effects are nested within the pair effects and so are not separately estimated; no time effects are included, for the reason given in Section 3. Time-invariant dyadic controls—bilateral distance and the common-border, common-language, and common-colonizer dummies—are absorbed by the pair fixed effects and are omitted from the tables; in ITPD-E, output, expenditure, and the multilateral resistance terms are additionally absorbed by the exporter-year and importer-year fixed effects. Connectivity variables enter as $\ln(1 + x)$; the ITU Regulatory Tracker, its four component clusters, the government-effectiveness percentile, and the OECD Digital Services Trade Restrictiveness Index (DSTRI) are scaled to the unit interval, with a higher DSTRI denoting a *more* restrictive regime.

Two features of the estimation warrant note. First, all specifications involving Africa interactions include the complete set of constituent lower-order interactions, so that the triple and quadruple terms measure differences in the relevant interaction rather than absorbing level shifts. Second, as discussed in Section 3, ITPD-E domestic flows are constructed as gross output less exports, and services-output coverage is highly unbalanced across African economies; Africa-specific coefficients estimated on ITPD-E therefore rest on a narrow base and several are estimated with very large standard errors. We report them for completeness and rely on the BaTiS estimates for the Africa margin.

Digital connectivity

Tables 14 and 15 report the connectivity estimates. In ITPD-E, fixed broadband penetration enters with a large, positive, and highly significant coefficient, mobile broadband is positive and significant but roughly half the size, download speed is positive for both technologies, and higher latency significantly reduces trade. In BaTiS, which separately identifies exporter and importer effects, fixed broadband is significant on the exporter margin while mobile broadband is insignificant on both margins, reproducing the fixed-over-mobile ordering found in ITPD-E at much smaller magnitudes. Of the quality measures, only mobile download speed is significant, on the exporter margin; fixed download speed is positive but insignificant. The latency estimates in BaTiS are negative on all four margins but imprecise. The speed and latency columns rest on the shorter sample for which Ookla data are available and are correspondingly less precise.

Table 14: *Digital connectivity and DDS trade, ITPD-E (full estimates)*

	(1) Fixed BB	(2) Mobile BB	(3) Fixed Speed	(4) Mobile Speed	(5) Fixed Lat	(6) Mobile Lat
Log(1+fixed BB) imp x INTL	0.6426***					
	(0.0449)					
RTA in force (Larch RTA database)	0.2390***	0.1459**	0.2252**	0.0339	0.1799*	0.0329
	(0.0585)	(0.0653)	(0.0938)	(0.0700)	(0.0990)	(0.0702)
Log(1+mobile BB) imp x INTL		0.3339***				
		(0.0279)				
Log(1+fixed speed) imp x INTL			0.2147***			
			(0.0155)			
Log(1+mobile speed) imp x INTL				0.1580***		
				(0.0201)		
Log(1+fixed latency) imp x INTL					-0.3751***	
					(0.0289)	
Log(1+mobile latency) imp x INTL						-0.3166***
						(0.0948)
Observations	414226	266970	216506	81706	172979	81706
Pseudo R-squared	0.9881	0.9868	0.9864	0.9824	0.9864	0.9824

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. Applied ICT goods tariffs are excluded from these specifications by design; see Table 26 and Table 27. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: *Digital connectivity and DDS trade, BaTiS (full estimates)*

	(1) Fixed BB	(2) Mobile BB	(3) Fixed Speed	(4) Mobile Speed	(5) Fixed Lat	(6) Mobile Lat
Log(1+fixed BB penetration) exporter	0.1349***					
	(0.0519)					
Log(1+fixed BB penetration) importer	-0.0004					
	(0.0541)					
Log GDP (exporter)	0.8019***	0.8020***	0.7228***	0.4926***	0.8176***	0.7434***
	(0.0874)	(0.1044)	(0.1202)	(0.0804)	(0.0953)	(0.1009)
Log GDP (importer)	0.6135***	0.5765***	0.5254***	0.1408	0.4942***	0.2985**
	(0.0730)	(0.0863)	(0.1132)	(0.1772)	(0.0676)	(0.1512)
Log population (exporter)	0.6840***	0.8497***	0.3893	0.7647	0.3499	1.2195**
	(0.2553)	(0.2935)	(0.3294)	(0.5730)	(0.3060)	(0.5675)
Log population (importer)	0.3198	0.2826	0.0434	-0.8009	0.3475	-0.2971
	(0.1975)	(0.2245)	(0.2152)	(0.8380)	(0.2274)	(0.7542)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.4255***	0.3121*	0.2410	-0.0326	0.3417**	0.2900
	(0.1275)	(0.1721)	(0.1858)	(0.3132)	(0.1486)	(0.3281)
Free trade agreement	0.1703***	0.1737***	0.1816***	0.1120***	0.1555*	0.1218***
	(0.0351)	(0.0408)	(0.0461)	(0.0276)	(0.0816)	(0.0320)
Log(1+mobile BB penetration) exporter		0.0249				
		(0.0314)				
Log(1+mobile BB penetration) importer		0.0290				
		(0.0333)				
Log(1+fixed DL speed) exporter			0.0541			
			(0.0334)			
Log(1+fixed DL speed) importer			0.0224			
			(0.0349)			
Log(1+mobile DL speed) exporter				0.0738**		
				(0.0349)		
Log(1+mobile DL speed) importer				0.0477		
				(0.0294)		
Log(1+fixed latency) exporter					-0.0774	
					(0.0655)	
Log(1+fixed latency) importer					-0.0337	
					(0.0436)	
Log(1+mobile latency) exporter						-0.0422
						(0.0700)
Log(1+mobile latency) importer						-0.0503
						(0.0807)
Observations	3721650	3019188	2211222	1256292	1424568	1256292
Pseudo R-squared	0.9217	0.9244	0.9183	0.9279	0.9242	0.9278

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1+x)$. Applied ICT goods tariffs are excluded from these specifications by design; see Table 26 and Table 27. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Regulatory quality and the African paradox

Tables 16 and 17 report the ITU Regulatory Tracker estimates. In both datasets the Tracker enters positively in the baseline (column 1), and the Africa interaction (column 2) is large and negative—relative to domestic trade in ITPD-E and on both margins in BaTiS—reproducing the African paradox. Columns (3) and (4) interact the Tracker with the government-effectiveness percentile. The interaction is positive and significant in ITPD-E and on the BaTiS importer margin, indicating that regulatory quality facilitates trade only above a threshold level of implementation capacity. In BaTiS the triple interactions are not statistically significant once the full constituent set is included, and the African shortfall operates through the lower-order terms; in ITPD-E the triple is significant but is offset by an almost equal and opposite $Gov.\ Eff.\ \times\ Africa$ term, and we do not interpret the pair.

Table 16: *ITU Regulatory Tracker, government effectiveness, and DDS trade, ITPD-E (full estimates)*

	(1) Baseline	(2) ITU x Afr	(3) ITU x GovEff	(4) Triple
ITU (imp) x INTL	3.8328***	3.8429***	-0.5582	-0.3544
	(0.2654)	(0.2658)	(1.3343)	(1.3846)
RTA in force (Larch RTA database)	0.1154*	0.1150*	0.1137*	0.1134*
	(0.0649)	(0.0649)	(0.0639)	(0.0639)
ITU x Africa x INTL		-10.5256***		-2.4342
		(2.1244)		(3.0473)
Gov eff (imp) x INTL			-5.6904***	-5.4949***
			(1.4832)	(1.5264)
ITU x Gov eff x INTL			4.9091***	4.6800***
			(1.5485)	(1.6008)
Gov eff x Africa x INTL				25.7309***
				(5.4084)
ITU x Gov eff x Africa x INTL				-26.9837***
				(7.0165)
Observations	314018	314018	309038	309038
Pseudo R-squared	0.9870	0.9870	0.9870	0.9870

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. Column (4) includes the full set of constituent lower-order interactions of the triple term; Africa × INTL is absorbed by the pair fixed effects. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Complementarity with enabling factors

Tables 18–21 report the complementarity estimates. Globally, the ITU Tracker interacts positively and significantly with electricity access, secondary-school enrolment, and fixed broadband penetration in both datasets; the mobile-broadband interaction is significant in BaTiS but not in ITPD-E. In the Africa specifications, the penalty operates chiefly through the lower-order $ITU \times Africa$ term, which is negative and significant on the BaTiS importer margin in three of the four specifications. The triple interactions are mostly imprecisely estimated once the full constituent set is included and do not identify which complement is responsible.

Table 17: *ITU Regulatory Tracker, government effectiveness, and DDS trade, BaTiS (full estimates)*

	(1) Baseline	(2) Africa	(3) Gov Eff	(4) Triple
ITU regulatory tracker (exporter, 0-1)	0.4642***	0.4690***	-0.2142	-0.1384
	(0.1741)	(0.1736)	(0.4179)	(0.4379)
ITU regulatory tracker (importer, 0-1)	0.2444	0.3108	-1.0527***	-0.8075**
	(0.2305)	(0.2366)	(0.3679)	(0.3967)
Log GDP (exporter)	0.8503***	0.8395***	0.8050***	0.7978***
	(0.0856)	(0.0861)	(0.0923)	(0.0933)
Log GDP (importer)	0.6121***	0.5924***	0.6201***	0.6080***
	(0.0680)	(0.0672)	(0.0683)	(0.0688)
Log population (exporter)	0.5039*	0.5424*	0.5353**	0.5587**
	(0.2792)	(0.2787)	(0.2587)	(0.2540)
Log population (importer)	0.1754	0.3055	0.2002	0.3107
	(0.2413)	(0.2236)	(0.1933)	(0.1928)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.4207***	0.4020***	0.3083**	0.3075**
	(0.1409)	(0.1374)	(0.1294)	(0.1303)
Free trade agreement	0.1652***	0.1597***	0.1199***	0.1212***
	(0.0350)	(0.0352)	(0.0384)	(0.0380)
ITU x Africa (exporter)		-0.8221*		-0.0226
		(0.4459)		(1.1433)
ITU x Africa (importer)		-1.4512***		-1.4293**
		(0.4858)		(0.6300)
Government effectiveness (exporter, 0-1)			-0.4272	-0.3615
			(0.4290)	(0.4463)
Government effectiveness (importer, 0-1)			-1.6069***	-1.4061***
			(0.4447)	(0.4397)
ITU x Gov eff (exporter)			0.8193	0.7273
			(0.5900)	(0.6186)
ITU x Gov eff (importer)			2.0541***	1.7421***
			(0.4871)	(0.5072)
Gov eff x Africa (exporter)				0.8010
				(1.4820)
Gov eff x Africa (importer)				-0.7137
				(0.9195)
ITU x Gov eff x Africa (exporter)				-1.6678
				(2.0752)
ITU x Gov eff x Africa (importer)				1.0150
				(1.2210)
Observations	3576762	3576762	3275046	3275046
Pseudo R-squared	0.9286	0.9287	0.9286	0.9286

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1+x)$. Column (4) includes the full set of constituent lower-order interactions of the triple term; the Africa main effect is time-invariant and absorbed by the pair fixed effects. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Alternative regulation measures

Tables 22–25 report the measurement results. Columns (1)–(4) examine the four ITU clusters individually while controlling for the summed depth of the remaining three; column (5) adds the bilateral regulatory-heterogeneity index; and column (6) uses the OECD Digital STRI. Table 28 additionally enters all four clusters jointly in ITPD-E; because the clusters are strongly collinear, we rely on the depth-controlled specifications. In BaTiS the Africa penalty concentrates in Cluster C3, the Regulatory Regime component that carries the strongest positive global effect, while the depth interactions are negative across the other clusters. The corresponding ITPD-E Africa interactions for C1 and C2 are very large and reflect the narrow African base noted above. The $DSTRI \times Africa$ interaction is positive in both datasets—insignificant in ITPD-E but significant on both BaTiS margins—so more restrictive regimes are, if anything, associated with more DDS trade in Africa. This reinforces the view that the paradox is not an artefact of how the ITU index is constructed.

Table 18: *Complementarity between regulation and enabling factors, ITPD-E (full estimates)*

	(1) Electricity	(2) Education	(3) Fixed BB	(4) Mobile BB	(5) Combined
ITU (imp) x INTL	-22.8241***	-5.5658***	0.4937	2.5056***	-23.4284***
	(5.5340)	(1.6787)	(0.5438)	(0.6216)	(6.0390)
Electricity (imp) x INTL	-15.6052***				-4.2325
	(3.7439)				(4.5972)
ITU x Electricity x INTL	26.6429***				16.0952**
	(5.5362)				(6.4457)
RTA in force (Larch RTA database)	0.1158*	0.1884***	0.1174*	0.0698	0.1932***
	(0.0649)	(0.0544)	(0.0641)	(0.0614)	(0.0545)
Education (imp) x INTL		-7.6957***			-9.1194***
		(1.3929)			(1.4668)
ITU x Education x INTL		8.6153***			10.1888***
		(1.5159)			(1.5908)
Fixed BB (imp) x INTL			-2.1716		
			(1.9762)		
ITU x Fixed BB x INTL			5.2429**		
			(2.0886)		
Mobile BB (imp) x INTL				-0.0812	
				(0.4521)	
ITU x Mobile BB x INTL				0.4558	
				(0.5275)	
Observations	314018	282387	310226	263394	282387
Pseudo R-squared	0.9870	0.9860	0.9872	0.9870	0.9860

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. A positive ITU $\times$ complement interaction indicates complementarity. Main effects are evaluated at a zero value of the interacted variable, which lies outside the observed range. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

ICT goods tariffs

Tables 26 and 27 report the tariff specifications discussed in Section 3. In each, the first two columns exclude the tariff and differ only in sample, isolating the coverage cost of requiring tariff data from the contribution of the control itself. The estimated tariff coefficient is an order of magnitude larger in ITPD-E than in BaTiS. Because ITPD-E identifies the term from the split of an importer's trade between international and domestic flows, and the domestic leg is constructed as gross output less exports, the ITPD-E coefficient absorbs measurement error in that construction; BaTiS contains no domestic flows and is not exposed to this channel. We therefore treat the BaTiS estimates as the credible ones.

Overall, this additional specification suggests that ICT goods tariffs may be relevant to the wider policy environment for digital services trade, but provides limited evidence of an independent tariff effect. The large negative ITPD-E estimate warrants caution given the construction of domestic trade flows, while the corresponding BaTiS estimates are statistically insignificant in the baseline and Africa-interaction specifications and significant at five per cent only for importers in the government-effectiveness specification. Importantly, controlling for tariffs leaves the main regulatory findings largely intact.

Robustness to the clustering scheme

Tables 29 and 30 compare clustering on country pairs with two-way clustering on exporter and importer (Egger & Tarlea, 2015). Because the country-specific variables of interest are monadic,

Table 19: *Africa heterogeneity in complementarity, ITPD-E (full estimates)*

	(1) Electricity	(2) Education	(3) Fixed BB	(4) Mobile BB
ITU (imp) x INTL	-17.5668*	-5.4045***	0.5278	2.5257***
	(9.3354)	(1.7126)	(0.5471)	(0.6237)
Electricity (imp) x INTL	-12.0879*			
	(6.4809)			
ITU x Electricity x INTL	21.3851**			
	(9.3288)			
ITU x Africa x INTL	-19.9543	-17.3843**	-5.8646***	10.1818
	(12.5455)	(8.2809)	(2.1763)	(6.7945)
Electricity x Africa x INTL	-22.9352*			
	(12.3727)			
ITU x Electricity x Africa x INTL	30.4547*			
	(16.0281)			
RTA in force (Larch RTA database)	0.1158*	0.1882***	0.1171*	0.0695
	(0.0649)	(0.0545)	(0.0641)	(0.0614)
Education (imp) x INTL		-7.5620***		
		(1.4189)		
ITU x Education x INTL		8.4677***		
		(1.5455)		
Education x Africa x INTL		-25.3853**		
		(10.9821)		
ITU x Education x Africa x INTL		27.7629**		
		(12.6309)		
Fixed BB (imp) x INTL			-2.0837	
			(1.9822)	
ITU x Fixed BB x INTL			5.1417**	
			(2.0961)	
Fixed BB x Africa x INTL			-203.2379	
			(415.7351)	
ITU x Fixed BB x Africa x INTL			236.8802	
			(506.3431)	
Mobile BB (imp) x INTL				-0.0732
				(0.4528)
ITU x Mobile BB x INTL				0.4457
				(0.5284)
Mobile BB x Africa x INTL				30.3292*
				(17.2727)
ITU x Mobile BB x Africa x INTL				-39.6315*
				(20.9463)
Observations	314018	282387	310226	263394
Pseudo R-squared	0.9870	0.9860	0.9872	0.9870

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1 + x)$. Each column includes the full set of constituent lower-order interactions, so the quadruple term measures the difference in the regulation–complement interaction for Africa. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

pair clustering treats each of a country's pairs as an independent draw of the same regressor. Point estimates are identical within each pair of columns; only the standard errors differ.

The two datasets behave differently, which is why they are clustered differently in the main tables. In BaTiS the two-way standard errors are larger for every coefficient in Table 30, by a factor of between roughly 1.5 and 2.4, and several coefficients that are significant under pair clustering are not significant under two-way clustering. The BaTiS results in the main text are therefore reported with two-way clustering. In ITPD-E the comparison is mixed: the two-way standard errors are larger for four of the six reported in Table 29, but smaller for the $ITU \times Africa$ interaction (1.79 against 2.12) and for the quadruple interaction (6.33 against 7.02). No coefficient in that table changes significance under either scheme, so the ITPD-E results in the main text retain pair clustering.

Table 20: *Complementarity between regulation and enabling factors, BaTiS (full estimates)*

	(1) Electricity	(2) Education	(3) Fixed BB	(4) Mobile BB	(5) Combined
ITU regulatory tracker (exporter, 0-1)	-0.6669	-0.9468	-0.0108	0.0561	-1.9091***
	(0.8607)	(1.0289)	(0.2158)	(0.2551)	(0.6378)
ITU regulatory tracker (importer, 0-1)	-2.0005***	-1.1787***	-0.2825	-0.1628	-3.2970***
	(0.6217)	(0.4554)	(0.1958)	(0.2538)	(1.0157)
Electricity access (exporter, 0-1)	-1.0242				0.6816
	(0.6855)				(0.7048)
Electricity access (importer, 0-1)	-1.9152***				-1.1532*
	(0.4836)				(0.6461)
ITU x Electricity (exporter)	1.1630				0.2934
	(0.8764)				(0.9848)
ITU x Electricity (importer)	2.3533***				2.3638**
	(0.6453)				(1.0438)
Log GDP (exporter)	0.8235***	0.8994***	0.7448***	0.7069***	0.8776***
	(0.0890)	(0.0952)	(0.1178)	(0.1155)	(0.0959)
Log GDP (importer)	0.6056***	0.5374***	0.5738***	0.5185***	0.5302***
	(0.0691)	(0.0616)	(0.0947)	(0.0970)	(0.0610)
Log population (exporter)	0.5579*	0.2976	0.4459*	0.2958	0.2845
	(0.2882)	(0.2885)	(0.2432)	(0.2420)	(0.2803)
Log population (importer)	0.3262	0.4970**	0.0838	-0.0525	0.5375**
	(0.2256)	(0.2153)	(0.2075)	(0.1965)	(0.2092)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.3654**	0.4584***	0.0310	-0.0356	0.4682***
	(0.1420)	(0.1397)	(0.1489)	(0.1526)	(0.1411)
Free trade agreement	0.1412***	0.1206***	0.0845**	0.0886**	0.1230***
	(0.0363)	(0.0318)	(0.0378)	(0.0391)	(0.0325)
Secondary enrollment (exporter, 0-1)		-1.3938*			-1.9503**
		(0.8159)			(0.8605)
Secondary enrollment (importer, 0-1)		-1.2200***			-1.0179***
		(0.4459)			(0.3575)
ITU x Secondary edu (exporter)		1.4178			2.0289*
		(0.9926)			(1.0660)
ITU x Secondary edu (importer)		1.4036***			1.1736***
		(0.4560)			(0.3358)
Fixed broadband (exporter, 0-1)			-0.5074		
			(0.9636)		
Fixed broadband (importer, 0-1)			-2.1100***		
			(0.7739)		
ITU x Fixed BB (exporter)			1.4373		
			(0.9881)		
ITU x Fixed BB (importer)			2.8867***		
			(0.8026)		
Mobile broadband (exporter, 0-1)				-0.2720	
				(0.2200)	
Mobile broadband (importer, 0-1)				-0.4046**	
				(0.1845)	
ITU x Mobile BB (exporter)				0.4627**	
				(0.2252)	
ITU x Mobile BB (importer)				0.6311***	
				(0.2128)	
Observations	3385638	1843584	3202170	2895192	1825770
Pseudo R-squared	0.9284	0.9272	0.9288	0.9300	0.9272

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1 + x)$. A positive ITU $\times$ complement interaction indicates complementarity. Column (5) includes electricity and education together. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 21: *Africa heterogeneity in complementarity, BaTiS (full estimates)*

	(1) Electricity	(2) Education	(3) Fixed BB	(4) Mobile BB
ITU regulatory tracker (exporter, 0-1)	-1.8795**	-0.8878	0.0176	0.0733
	(0.7500)	(1.0972)	(0.2255)	(0.2629)
ITU regulatory tracker (importer, 0-1)	-1.5388	-0.5684	-0.1985	-0.0803
	(0.9708)	(0.4252)	(0.2058)	(0.2616)
Electricity access (exporter, 0-1)	-1.6104**			
	(0.6289)			
Electricity access (importer, 0-1)	-1.3093**			
	(0.6196)			
ITU x Electricity (exporter)	2.3849***			
	(0.7619)			
ITU x Electricity (importer)	1.8932**			
	(0.9519)			
ITU x Africa (exporter)	2.8603**	-0.1344	-0.3104	-0.0827
	(1.3967)	(1.1141)	(0.4022)	(0.6682)
ITU x Africa (importer)	0.3545	-3.4694***	-0.7662*	-1.0548**
	(1.0803)	(1.2498)	(0.4554)	(0.4235)
Electricity x Africa (exp)	2.2028			
	(1.4381)			
Electricity x Africa (imp)	0.2122			
	(0.9851)			
ITU x Electricity x Africa (exp)	-4.2066**			
	(1.7007)			
ITU x Electricity x Africa (imp)	-1.5544			
	(1.3881)			
Secondary enrollment (exporter, 0-1)		-1.3380		
		(0.8816)		
Secondary enrollment (importer, 0-1)		-0.6610		
		(0.4653)		
ITU x Secondary edu (exporter)		1.3544		
		(1.0644)		
ITU x Secondary edu (importer)		0.7900*		
		(0.4557)		
Education x Africa (exp)		0.5549		
		(0.9914)		
Education x Africa (imp)		-2.0716*		
		(1.0685)		
ITU x Education x Africa (exp)		-0.4597		
		(1.1376)		
ITU x Education x Africa (imp)		2.7877**		
		(1.3318)		
Fixed broadband (exporter, 0-1)			-0.4149	
			(0.9803)	
Fixed broadband (importer, 0-1)			-1.9271**	
			(0.7551)	
ITU x Fixed BB (exporter)			1.3401	
			(1.0117)	
ITU x Fixed BB (importer)			2.5797***	
			(0.7872)	
Fixed BB x Africa (exp)			-3.1078	
			(2.0615)	
Fixed BB x Africa (imp)			-3.9693	
			(5.1269)	
ITU x Fixed BB x Africa (exp)			2.3509	
			(3.0946)	
ITU x Fixed BB x Africa (imp)			3.4754	
			(6.0449)	
Mobile broadband (exporter, 0-1)				-0.2662
				(0.2223)
Mobile broadband (importer, 0-1)				-0.3734**
				(0.1879)
ITU x Mobile BB (exporter)				0.4516**
				(0.2288)
ITU x Mobile BB (importer)				0.5867***
				(0.2165)
Mobile BB x Africa (exp)				0.0716
				(0.3905)
Mobile BB x Africa (imp)				-0.1533
				(0.4259)
ITU x Mobile BB x Africa (exp)				-0.1755
				(0.4937)
ITU x Mobile BB x Africa (imp)				0.1942
				(0.5532)
Observations	3385638	1843584	3202170	2895192
Pseudo R-squared	0.9285	0.9272	0.9288	0.9300

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1 + x)$. Each column includes the full set of constituent lower-order interactions, so the triple term measures the difference in the regulation–complement interaction for Africa. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 22: *Alternative regulation measures: ITU clusters, ITPD-E (full estimates)*

	(1) C1+Depth	(2) C2+Depth	(3) C3+Depth	(4) C4+Depth	(5) Hetero	(6) DSTRI
ITU C1 x INTL	1.6836					
	(1.9884)					
Depth excl C1 x INTL	4.1206***					
	(0.3886)					
RTA in force (Larch RTA database)	0.1199*	0.1163*	0.1157*	0.1173*	0.1079*	0.1036*
	(0.0653)	(0.0642)	(0.0648)	(0.0646)	(0.0602)	(0.0583)
ITU C2 x INTL		3.4069**				
		(1.7039)				
Depth excl C2 x INTL		3.9292***				
		(0.4076)				
ITU C3 x INTL			3.9054***			
			(0.7178)			
Depth excl C3 x INTL			3.7636***			
			(0.8307)			
ITU C4 x INTL				4.9052***		
				(1.4536)		
Depth excl C4 x INTL				3.5484***		
				(0.3767)		
ITU heterogeneity x INTL					0.1473	
					(0.1298)	
DSTRI x INTL						2.1172***
						(0.3983)
Observations	314018	314018	314018	314018	265804	132310
Pseudo R-squared	0.9870	0.9870	0.9870	0.9870	0.8756	0.9862

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. C1=Authority, C2=Mandate, C3=Regime, C4=Competition. Depth is the sum of the other three clusters. The DSTRI is the OECD Digital STRI, untransformed, so higher values denote a more restrictive regime. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 23: *Africa heterogeneity by regulatory component, ITPD-E (full estimates)*

	(1) C1xAfr	(2) C2xAfr	(3) C3xAfr	(4) C4xAfr	(5) HeteroxAfr	(6) DSTRIxAfr
ITU C1 x INTL	1.7608					
	(1.9885)					
Depth excl C1 x INTL	4.1211***					
	(0.3890)					
ITU C1 x Africa x INTL	-61.8419***					
	(23.0367)					
Depth C1 x Africa x INTL	-4.9435					
	(3.4243)					
RTA in force (Larch RTA database)	0.1193*	0.1159*	0.1153*	0.1168*	0.1079*	0.1036*
	(0.0653)	(0.0642)	(0.0648)	(0.0646)	(0.0602)	(0.0583)
ITU C2 x INTL		3.3626**				
		(1.7065)				
Depth excl C2 x INTL		3.9509***				
		(0.4088)				
ITU C2 x Africa x INTL		-135.5897***				
		(44.7195)				
Depth C2 x Africa x INTL		-8.2482***				
		(1.9824)				
ITU C3 x INTL			3.9106***			
			(0.7181)			
Depth excl C3 x INTL			3.7773***			
			(0.8310)			
ITU C3 x Africa x INTL			-0.7858			
			(6.3913)			
Depth C3 x Africa x INTL			-24.3294***			
			(7.8999)			
ITU C4 x INTL				4.9216***		
				(1.4545)		
Depth excl C4 x INTL				3.5570***		
				(0.3768)		
ITU C4 x Africa x INTL				-0.4288		
				(13.5878)		
Depth C4 x Africa x INTL				-13.8418**		
				(5.7715)		
ITU heterogeneity x INTL					0.1491	
					(0.1322)	
ITU heterogeneity x Africa x INTL					-0.0786	
					(0.3565)	
DSTRI x INTL						2.1171***
						(0.3983)
DSTRI x Africa x INTL						3.8478
						(3.7104)
Observations	314018	314018	314018	314018	265804	132310
Pseudo R-squared	0.9870	0.9870	0.9870	0.9870	0.8756	0.9862

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. C1=Authority, C2=Mandate, C3=Regime, C4=Competition. Depth is the sum of the other three clusters. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 24: *Alternative regulation measures, BaTiS (full estimates)*

	(1) C1+Depth	(2) C2+Depth	(3) C3+Depth	(4) C4+Depth	(5) Hetero	(6) DSTRI
ITU Cluster C1 (exporter, 0-1)	-1.7035**					
	(0.8066)					
ITU Cluster C1 (importer, 0-1)	-0.0019					
	(0.7397)					
ITU depth excl C1 (exporter, 0-3)	0.8701***					
	(0.1552)					
ITU depth excl C1 (importer, 0-3)	0.2339					
	(0.2046)					
ITU Cluster C2 (exporter, 0-1)		0.5552				
		(1.1792)				
ITU Cluster C2 (importer, 0-1)		1.2673				
		(0.7720)				
ITU depth excl C2 (exporter, 0-3)		0.4503				
		(0.2896)				
ITU depth excl C2 (importer, 0-3)		0.0401				
		(0.3238)				
ITU Cluster C3 (exporter, 0-1)			1.7984***			
			(0.3843)			
ITU Cluster C3 (importer, 0-1)			0.6017*			
			(0.3603)			
ITU depth excl C3 (exporter, 0-3)			-0.4852			
			(0.3221)			
ITU depth excl C3 (importer, 0-3)			-0.1263			
			(0.2749)			
ITU Cluster C4 (exporter, 0-1)				-0.5617		
				(0.6165)		
ITU Cluster C4 (importer, 0-1)				-0.9503		
				(0.6546)		
ITU depth excl C4 (exporter, 0-3)				0.8128***		
				(0.3119)		
ITU depth excl C4 (importer, 0-3)				0.6536**		
				(0.3049)		
ITU regulatory tracker (exporter, 0-1)					0.4452***	
					(0.1618)	
ITU regulatory tracker (importer, 0-1)					0.2551	
					(0.2063)	
ITU heterogeneity index (0-1)					-0.0268	
					(0.1235)	
Digital STRI, restrictiveness (exporter)						0.0661
						(0.3541)
Digital STRI, restrictiveness (importer)						-0.3461
						(0.3970)
Observations	3576762	3576762	3576762	3576762	3190200	469920
Pseudo R-squared	0.9287	0.9286	0.9287	0.9287	0.9278	0.9280

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1 + x)$. C1=Authority, C2=Mandate, C3=Regime, C4=Competition. Depth is the sum of the other three clusters. The DSTRI is the OECD Digital STRI, untransformed, so higher values denote a more restrictive regime. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 25: *Africa heterogeneity by regulatory component, BaTiS (full estimates)*

	(1) C1xAfr	(2) C2xAfr	(3) C3xAfr	(4) C4xAfr	(5) HeteroxAfr	(6) DSTRIxAfr
ITU Cluster C1 (exporter, 0-1)	-1.7899**					
	(0.8222)					
ITU Cluster C1 (importer, 0-1)	-0.0724					
	(0.7821)					
ITU depth excl C1 (exporter, 0-3)	0.8867***					
	(0.1578)					
ITU depth excl C1 (importer, 0-3)	0.3108					
	(0.2136)					
ITU C1 x Africa (exporter)	3.9244***					
	(1.2852)					
ITU C1 x Africa (importer)	2.2998					
	(1.4634)					
Depth excl C1 x Africa (exporter)	-1.7245***					
	(0.5254)					
Depth excl C1 x Africa (importer)	-2.1744***					
	(0.6873)					
ITU Cluster C2 (exporter, 0-1)		0.5385				
		(1.1939)				
ITU Cluster C2 (importer, 0-1)		1.0962				
		(0.7986)				
ITU depth excl C2 (exporter, 0-3)		0.4608				
		(0.2912)				
ITU depth excl C2 (importer, 0-3)		0.1480				
		(0.3416)				
ITU C2 x Africa (exporter)		-1.4675				
		(1.9191)				
ITU C2 x Africa (importer)		1.9111				
		(1.7797)				
Depth excl C2 x Africa (exporter)		-0.7202				
		(0.6989)				
Depth excl C2 x Africa (importer)		-1.9389***				
		(0.7124)				
ITU Cluster C3 (exporter, 0-1)			1.8191***			
			(0.3880)			
ITU Cluster C3 (importer, 0-1)			0.7739**			
			(0.3603)			
ITU depth excl C3 (exporter, 0-3)			-0.4996			
			(0.3336)			
ITU depth excl C3 (importer, 0-3)			-0.1480			
			(0.2790)			
ITU C3 x Africa (exporter)			-2.9614**			
			(1.1902)			
ITU C3 x Africa (importer)			-3.5523***			
			(0.9519)			
Depth excl C3 x Africa (exporter)			0.7635			
			(0.4914)			
Depth excl C3 x Africa (importer)			0.2030			
			(0.6310)			
ITU Cluster C4 (exporter, 0-1)				-0.5484		
				(0.6348)		
ITU Cluster C4 (importer, 0-1)				-0.8807		
				(0.6916)		
ITU depth excl C4 (exporter, 0-3)				0.8141***		
				(0.3157)		
ITU depth excl C4 (importer, 0-3)				0.7177**		
				(0.3137)		
ITU C4 x Africa (exporter)				0.0325		
				(1.0323)		
ITU C4 x Africa (importer)				-1.5905		
				(1.4200)		
Depth excl C4 x Africa (exporter)				-1.0970*		
				(0.6338)		
Depth excl C4 x Africa (importer)				-1.3969**		
				(0.6248)		
ITU regulatory tracker (exporter, 0-1)					0.4431***	
					(0.1620)	
ITU regulatory tracker (importer, 0-1)					0.2551	
					(0.2062)	
ITU heterogeneity index (0-1)					-0.0444	
					(0.1274)	
ITU heterogeneity x Africa (bilateral)					0.2736	
					(0.1966)	
Digital STRI, restrictiveness (exporter)						0.0262
						(0.3662)
Digital STRI, restrictiveness (importer)						-0.3977
						(0.4114)
DSTRI restrictiveness x Africa (exporter)						1.0180**
						(0.5013)
DSTRI restrictiveness x Africa (importer)						1.1427**
						(0.5017)
Observations	3576762	3576762	3576762	3576762	3190200	469920
Pseudo R-squared	0.9287	0.9287	0.9288	0.9287	0.9278	0.9280

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1+x)$. C1=Authority, C2=Mandate, C3=Regime, C4=Competition. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 26: *Regulatory quality and DDS trade with and without ICT tariffs, ITPD-E (full estimates)*

	ITU baseline			ITU x Africa		ITU x Gov effectiveness	
	(1) Full sample	(2) Tariff sample	(3) With tariff	(4) No tariff	(5) With tariff	(6) No tariff	(7) With tariff
ITU (imp) x INTL	3.8328***	3.8262***	2.7017***	3.8365***	2.7167***	-0.7620	-1.3478
	(0.2654)	(0.2703)	(0.2484)	(0.2707)	(0.2493)	(1.3793)	(1.2787)
RTA in force (Larch RTA database)	0.1154*	0.1183*	0.1031	0.1179*	0.1028	0.1151*	0.1015
	(0.0649)	(0.0654)	(0.0645)	(0.0654)	(0.0645)	(0.0645)	(0.0638)
Log(1+ICT tariff) imp x INTL			-16.1590***		-16.0657***		-16.9670***
			(1.9475)		(1.9493)		(1.9898)
ITU x Africa x INTL				-10.6412***	-8.8917***		
				(2.1423)	(2.1866)		
Gov eff (imp) x INTL						-5.9064***	-3.5438**
						(1.5379)	(1.4185)
ITU x Gov eff x INTL						5.1197***	4.6652***
						(1.5976)	(1.4810)
Observations	314018	271025	271025	271025	271025	266357	266357
Pseudo R-squared	0.9870	0.9869	0.9869	0.9869	0.9869	0.9869	0.9869

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. With importer-time fixed effects absorbing the tariff level, the ICT tariff term is identified from the composition of trade between international and domestic flows and is reported as a conditional correlation rather than a tariff elasticity. Columns (1) and (2) exclude the tariff and differ only in sample: column (2) is restricted to observations for which the tariff is observed, so comparing columns (1) and (2) isolates the change in coverage and comparing columns (2) and (3) isolates the contribution of the control. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 27: *Regulatory quality and DDS trade with and without ICT tariffs, BaTiS (full estimates)*

	ITU baseline			ITU x Africa		ITU x Gov effectiveness	
	(1) Full sample	(2) Tariff sample	(3) With tariff	(4) No tariff	(5) With tariff	(6) No tariff	(7) With tariff
ITU regulatory tracker (exporter, 0-1)	0.4642***	0.4294***	0.4068**	0.4295***	0.4078**	-0.4107	-0.5716
	(0.1741)	(0.1652)	(0.1686)	(0.1632)	(0.1674)	(0.4722)	(0.5431)
ITU regulatory tracker (importer, 0-1)	0.2444	0.3069	0.2602	0.3787*	0.3432	-1.2757***	-1.5091***
	(0.2305)	(0.2222)	(0.2212)	(0.2275)	(0.2251)	(0.3761)	(0.3585)
Log GDP (exporter)	0.8503***	0.8331***	0.8117***	0.8213***	0.8040***	0.8125***	0.7744***
	(0.0856)	(0.0908)	(0.0926)	(0.0914)	(0.0931)	(0.0981)	(0.0977)
Log GDP (importer)	0.6121***	0.6078***	0.5829***	0.5842***	0.5662***	0.6198***	0.5771***
	(0.0680)	(0.0694)	(0.0759)	(0.0680)	(0.0738)	(0.0693)	(0.0748)
Log population (exporter)	0.5039*	0.6084**	0.6074*	0.6448**	0.6475**	0.6025**	0.5914**
	(0.2792)	(0.3024)	(0.3134)	(0.3001)	(0.3111)	(0.2693)	(0.2799)
Log population (importer)	0.1754	0.3207	0.3517	0.4855**	0.5002**	0.2553	0.3155
	(0.2413)	(0.2703)	(0.2745)	(0.2436)	(0.2488)	(0.2091)	(0.2084)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.4207***	0.4058***	0.3644**	0.3831***	0.3507**	0.2803**	0.2035
	(0.1409)	(0.1396)	(0.1428)	(0.1355)	(0.1387)	(0.1266)	(0.1283)
Free trade agreement	0.1652***	0.1449***	0.1386***	0.1392***	0.1342***	0.1081***	0.0943**
	(0.0350)	(0.0356)	(0.0351)	(0.0357)	(0.0355)	(0.0400)	(0.0407)
Log(1+ICT tariff), exporter			-0.8811		-0.8256		-1.4670
			(0.9738)		(0.9664)		(1.2075)
Log(1+ICT tariff), importer			-1.2720		-0.8870		-2.3824**
			(1.1495)		(1.0987)		(1.1194)
ITU x Africa (exporter)				-0.9971**	-0.9649**		
				(0.4423)	(0.4365)		
ITU x Africa (importer)				-1.7174***	-1.6660***		
				(0.5949)	(0.5964)		
Government effectiveness (exporter, 0-1)						-0.6650	-0.6787
						(0.5023)	(0.5483)
Government effectiveness (importer, 0-1)						-1.8638***	-1.9865***
						(0.4912)	(0.4755)
ITU x Gov eff (exporter)						1.0389	1.1880
						(0.6818)	(0.7426)
ITU x Gov eff (importer)						2.3635***	2.5802***
						(0.5128)	(0.4875)
Observations	3576762	2189556	2189556	2189556	2189556	2140548	2140548
Pseudo R-squared	0.9286	0.9284	0.9284	0.9285	0.9285	0.9288	0.9288

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1+x)$. Because BaTiS contains no domestic flows, the ICT tariff enters directly rather than interacted with an international dummy and is identified from within-pair variation in applied tariffs over time. Columns (2)–(7) are estimated on the sample for which both partners' tariffs are observed; column (1) uses the full sample, so comparing columns (1) and (2) isolates the change in coverage and comparing columns (2) and (3) isolates the contribution of the control. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

Table 28: *All four ITU clusters entered jointly, ITPD-E (full estimates)*

	(1) All clusters
ITU C1 x INTL	1.7884
	(2.0260)
ITU C2 x INTL	3.7520**
	(1.7404)
ITU C3 x INTL	3.9049***
	(0.7077)
ITU C4 x INTL	4.8878***
	(1.4367)
RTA in force (Larch RTA database)	0.1209*
	(0.0645)
Observations	314018
Pseudo R-squared	0.9870

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. Standard errors clustered on country pairs. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. All four ITU clusters are entered simultaneously rather than one at a time with a depth control. The clusters are strongly collinear, so the individual coefficients here are less reliable than the depth-controlled specifications in Table 22; the table is reported for completeness. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 29: *Robustness to the clustering scheme, ITPD-E (full estimates)*

	(1) FixedBB pair	(2) FixedBB 2w	(3) ITUxAfr pair	(4) ITUxAfr 2w	(5) Triple pair	(6) Triple 2w
Log(1+fixed BB) imp x INTL	0.6426***	0.6426***				
	(0.0449)	(0.1026)				
ITU (imp) x INTL			3.8429***	3.8429***	-0.3544	-0.3544
			(0.2658)	(0.4787)	(1.3846)	(2.8325)
ITU x Africa x INTL			-10.5256***	-10.5256***	-2.4342	-2.4342
			(2.1244)	(1.7917)	(3.0473)	(3.4776)
ITU x Gov eff x Africa x INTL					-26.9837***	-26.9837***
					(7.0165)	(6.3312)
Observations	414226	414226	314018	314018	309038	309038

Notes: PPML with exporter-year, importer-year, country-pair and industry fixed effects. All importer variables enter interacted with the international dummy. Log transforms use $\ln(1+x)$. Odd columns cluster on country pairs; even columns cluster two-way on exporter and importer following Egger & Tarlea (2015). Point estimates are identical within each pair of columns; only standard errors differ. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 30: *Robustness to the clustering scheme, BaTiS (full estimates)*

	(1) FixedBB pair	(2) FixedBB 2w	(3) MobBB pair	(4) MobBB 2w	(5) Africa pair	(6) Africa 2w	(7) Triple pair	(8) Triple 2w
Log(1+fixed BB penetration) exporter	0.1349***	0.1349***						
	(0.0356)	(0.0519)						
Log(1+fixed BB penetration) importer	-0.0004	-0.0004						
	(0.0293)	(0.0541)						
Log(1+mobile BB penetration) exporter			0.0249	0.0249				
			(0.0178)	(0.0314)				
Log(1+mobile BB penetration) importer			0.0290*	0.0290				
			(0.0165)	(0.0333)				
ITU regulatory tracker (exporter, 0-1)					0.4690***	0.4690***	-0.1384	-0.1384
					(0.1153)	(0.1736)	(0.1905)	(0.4379)
ITU regulatory tracker (importer, 0-1)					0.3108***	0.3108	-0.8075***	-0.8075**
					(0.1091)	(0.2366)	(0.2220)	(0.3967)
ITU x Africa (exporter)					-0.8221***	-0.8221*	-0.0226	-0.0226
					(0.2329)	(0.4459)	(0.6277)	(1.1433)
ITU x Africa (importer)					-1.4512***	-1.4512***	-1.4293***	-1.4293**
					(0.2004)	(0.4858)	(0.3385)	(0.6300)
Government effectiveness (exporter, 0-1)							-0.3615	-0.3615
							(0.2332)	(0.4463)
Government effectiveness (importer, 0-1)							-1.4061***	-1.4061***
							(0.2390)	(0.4397)
ITU x Gov eff (exporter)							0.7273**	0.7273
							(0.2900)	(0.6186)
ITU x Gov eff (importer)							1.7421***	1.7421***
							(0.3034)	(0.5072)
Gov eff x Africa (exporter)							0.8010	0.8010
							(0.8162)	(1.4820)
Gov eff x Africa (importer)							-0.7137	-0.7137
							(0.5308)	(0.9195)
ITU x Gov eff x Africa (exporter)							-1.6678	-1.6678
							(1.1498)	(2.0752)
ITU x Gov eff x Africa (importer)							1.0150	1.0150
							(0.6668)	(1.2210)
Observations	3721650	3721650	3019188	3019188	3576762	3576762	3275046	3275046

Notes: PPML with country-pair and sector fixed effects. Country-time-varying controls: log GDP and log population of both partners, and the Baier–Bergstrand multilateral resistance correction. Log transforms use $\ln(1+x)$. Odd columns cluster on country pairs; even columns cluster two-way on exporter and importer following Egger & Tarlea (2015). Point estimates are identical within each pair of columns; only standard errors differ. The triple-interaction columns use the same full constituent set as Table 17. * $p<0.10$, ** $p<0.05$, *** $p<0.01$

D Robustness: excluding modelled BaTiS observations

The WTO–OECD BaTiS matrix is balanced, and its cells are not all reported. The release records, for every cell, the method by which the value was obtained: reported by a national or international source, estimated from reported information, modelled, or neither reported nor modelled. Because the modelling step is itself gravity-based, estimating a gravity equation on those cells risks recovering the model that generated them rather than an economic relationship. This appendix reports the entire BaTiS analysis of Section 3 with every modelled cell removed.

The restriction

A cell is treated as modelled where its method code begins with `M`. Table 13 in Appendix B reports the composition of the matrix and the characteristics of the cells on either side of the restriction. Two features of that table govern how the results below should be read.

First, the restriction is severe. Modelled cells are 72 per cent of the DDS matrix, so the estimation samples here retain between 26 and 28 per cent of their full-sample counterparts. Standard errors roughly double as a result, and several coefficients that are significant in the full sample lose significance here on point estimates that barely move. Where that happens we read it as a loss of power rather than as evidence against the full-sample result.

Second, and more reassuringly, the restriction is close to neutral on observables. One might expect modelling to be concentrated among economies with weak statistical capacity, which would make the retained sample richer and better connected and would truncate the lower tail of every regressor correlated with income. The normalised differences in Table 13 are all below 0.09 in absolute value, far inside the conventional 0.25 threshold, and the share of cells modelled is essentially flat across quartiles of exporter income. Pairs involving an African economy are modelled slightly more often than others, 75 against 70 per cent, but the gap is small. The restricted sample is therefore smaller than the full one without being systematically different from it in the dimensions that matter for these regressions.

What survives

Every result on which Section 3 rests survives, and several are stronger under the restriction than in the full sample.

Connectivity. The fixed-broadband exporter elasticity is 0.160 (0.070), against 0.135 (0.052) in the full sample: significant in both, and larger here. Mobile broadband remains insignificant on both margins. Fixed download speed becomes significant on the exporter margin, at 0.086 (0.031). Latency is negative on all four margins in both samples.

Complementarity. All four ITU–complement interactions remain positive and significant on the importer margin: electricity 6.941 (1.864), education 1.289 (0.556), fixed broadband 2.421 (0.667) and mobile broadband 0.608 (0.189). The electricity interaction is nearly three times its full-sample value, but the ITU main effect scales with it, so the implied switch point moves only from 0.85 to 0.95. The other three switch points are essentially unchanged, at 0.85 for education,

0.11 for fixed broadband and 0.30 for mobile broadband. On the exporter margin the education and fixed-broadband interactions, insignificant in the full sample, become significant here.

Implementation capacity. The interaction of the Tracker with government effectiveness on the importer margin is 2.222 (0.526), against 2.054 (0.487) in the full sample.

The African penalty. In the implementation-gap specification the $ITU \times Africa$ interaction is −1.378 (0.611) on the importer margin and −1.545 (0.673) on the exporter margin; the exporter estimate, marginally significant in the full sample, strengthens here.

The Regulatory Regime component. Cluster C3 retains its positive global exporter effect, 2.049 (0.541), and its Africa interactions remain negative and significant on both margins, at −4.534 (2.038) for exporters and −6.233 (2.888) for importers—in both cases larger than in the full sample. The concentration of the African regulatory penalty in C3, which is the mechanism Section 3 advances, is therefore not an artefact of the modelled cells.

What does not survive, and why

Three qualifications are worth stating explicitly.

In the complementarity specifications with Africa interactions, the $ITU \times Africa$ terms for fixed broadband (−1.020) and mobile broadband (−0.946) lose significance as their standard errors roughly double. The point estimates are close to their full-sample values of −0.766 and −1.055, so this is a precision loss rather than a reversal. The education interaction moves in the opposite direction, from −3.469 to −8.977, and remains significant at one per cent.

The triple interactions are unstable and should not be interpreted in either sample. In the implementation-gap specification the $ITU \times Gov.\ Eff. \times Africa$ term on the importer margin is 1.015 and insignificant in the full sample but 6.329 (2.184) here, alongside a constituent $Gov.\ Eff. \times Africa$ term of −5.180 (1.728). In the complementarity specifications the fixed-broadband triple carries a standard error of 17.4 on the importer margin. These terms are evaluated where African fixed-broadband penetration averages about two per cent of its unit range, and the restricted sample leaves too little African variation to identify them. Section 3 already treats the triples as uninformative; that judgement applies with more force here.

The restricted sample is also more sensitive to the choice of clustering. Under pair clustering several of the Africa interactions are significant at one per cent where two-way clustering by exporter and importer leaves them marginal. Two-way clustering remains the reported default throughout, for the reasons set out in Section 3.

Reading the two samples together

The estimates that carry the argument—the fixed-broadband exporter elasticity, the four complementarity interactions, the implementation-capacity interaction, the African regulatory penalty, and its concentration in the Regulatory Regime component—are all present, correctly signed and statistically significant in a sample from which every modelled cell has been removed, and in several cases they are larger there. What the restriction costs is precision, concentrated in

the interaction terms that were already the least well identified.

We therefore report the full BaTiS sample in the main text, on the grounds that it is four times larger and no less representative on observables, and treat the estimates in this appendix as the robustness check that the concern warrants.

The eight tables corresponding to Section 3, estimated on the restricted sample, follow. Each is the direct counterpart of a table in Appendix C.

Table 31: *Digital Connectivity Effects on Services Trade (excluding modelled BaTiS observations)*

	(1) Fixed BB	(2) Mobile BB	(3) Fixed speed	(4) Mobile speed	(5) Fixed latency	(6) Mobile latency
Log(1+fixed BB pen.), exp.	0.1600**					
	(0.0699)					
Log(1+fixed BB pen.), imp.	0.0059					
	(0.0649)					
Log GDP (exp.)	0.7931***	0.7922***	0.7041***	0.5104***	0.8466***	0.7046***
	(0.0990)	(0.1179)	(0.1372)	(0.1079)	(0.1028)	(0.0858)
Log GDP (imp.)	0.5576***	0.5165***	0.4955***	0.2077	0.5122***	0.3583***
	(0.0835)	(0.0995)	(0.1307)	(0.1489)	(0.0616)	(0.1023)
Log population (exp.)	0.7226**	0.6855*	0.0907	0.1548	0.2212	0.6177
	(0.3555)	(0.3554)	(0.3923)	(0.5152)	(0.3568)	(0.4842)
Log population (imp.)	0.8427***	0.8569***	0.4619	0.0301	0.7123**	0.5151
	(0.2816)	(0.2940)	(0.3299)	(0.5331)	(0.2872)	(0.4715)
Baier-Bergstrand MTR term	0.4112***	0.2555	0.2674	0.2205	0.3871**	0.6153***
	(0.1432)	(0.1841)	(0.1968)	(0.2794)	(0.1592)	(0.1983)
Free trade agreement	0.1510***	0.1328**	0.1446**	0.1110***	0.1172	0.1140***
	(0.0487)	(0.0546)	(0.0639)	(0.0272)	(0.0905)	(0.0352)
Log(1+mobile BB pen.), exp.		0.0655				
		(0.0400)				
Log(1+mobile BB pen.), imp.		0.0272				
		(0.0338)				
Log(1+fixed DL speed), exp.			0.0855***			
			(0.0310)			
Log(1+fixed DL speed), imp.			0.0065			
			(0.0405)			
Log(1+mobile DL speed), exp.				0.0419		
				(0.0340)		
Log(1+mobile DL speed), imp.				0.0732***		
				(0.0213)		
Log(1+fixed latency), exp.					-0.0546	
					(0.0745)	
Log(1+fixed latency), imp.					-0.0397	
					(0.0452)	
Log(1+mobile latency), exp.						-0.0664*
						(0.0358)
Log(1+mobile latency), imp.						-0.1541***
						(0.0453)
Observations	999941	785267	575102	294381	371217	294381
Pseudo R-squared	0.9309	0.9324	0.9283	0.9364	0.9270	0.9364

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP, log population, and RTA-augmented remoteness of both partners (see text; the distance-only remoteness index is not identified alongside pair fixed effects). Time-invariant bilateral variables (distance, contiguity, common language, common colonizer) are absorbed by the pair fixed effects. Connectivity variables in logs using ln(1+x) to handle zeros. exp./imp. = exporter/importer; BB = broadband; pen. = penetration; DL = download.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 32: *Implementation Gap Hypothesis: Government Effectiveness (excluding modelled BaTiS observations)*

	(1) Baseline	(2) Africa	(3) Gov Eff	(4) Triple
ITU regulatory tracker (exporter, 0-1)	0.4674*	0.4663*	-0.2989	-0.2294
	(0.2752)	(0.2742)	(0.4491)	(0.4797)
ITU regulatory tracker (importer, 0-1)	0.2529	0.2983	-1.2345***	-1.0308***
	(0.2702)	(0.2774)	(0.3760)	(0.3869)
Log GDP (exporter)	0.8603***	0.8569***	0.8253***	0.8226***
	(0.0956)	(0.0960)	(0.1006)	(0.1008)
Log GDP (importer)	0.5523***	0.5378***	0.5843***	0.5708***
	(0.0757)	(0.0764)	(0.0773)	(0.0779)
Log population (exporter)	0.5234	0.5406	0.5858*	0.6035**
	(0.3490)	(0.3482)	(0.3059)	(0.3009)
Log population (importer)	0.7617**	0.8357***	0.6697**	0.7927***
	(0.3253)	(0.3149)	(0.2814)	(0.2674)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.4041**	0.3920**	0.3085**	0.3094**
	(0.1576)	(0.1551)	(0.1390)	(0.1437)
Free trade agreement	0.1483***	0.1428***	0.1046*	0.1046*
	(0.0487)	(0.0487)	(0.0549)	(0.0613)
ITU x Africa (exporter)		-1.5450**		-0.4495
		(0.6726)		(0.7603)
ITU x Africa (importer)		-1.3775**		-4.6694***
		(0.6107)		(1.3456)
Government effectiveness (exporter, 0-1)			-0.5271	-0.4605
			(0.4666)	(0.4877)
Government effectiveness (importer, 0-1)			-1.7559***	-1.5583***
			(0.5547)	(0.5123)
ITU x Gov eff (exporter)			0.8715	0.7751
			(0.6199)	(0.6525)
ITU x Gov eff (importer)			2.2218***	1.9569***
			(0.5264)	(0.5126)
Gov eff x Africa (exporter)				4.2743**
				(1.9450)
Gov eff x Africa (importer)				-5.1802***
				(1.7276)
ITU x Gov eff x Africa (exporter)				-3.7892*
				(2.2127)
ITU x Gov eff x Africa (importer)				6.3294***
				(2.1839)
Observations	965571	965571	879206	879206
Pseudo R-squared	0.9322	0.9322	0.9323	0.9324

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners. All regulation and complement variables on a 0-1 scale. Column 4 includes every constituent lower-order interaction of the triple term; the Africa main effect is time-invariant and absorbed by the pair fixed effects. The marginal effect of regulation in Africa is reported in the text and is not the simple sum of the main and triple coefficients. Applied ICT goods tariffs are excluded from these specifications, which are intended to identify the effect of regulatory quality independently of trade policy; specifications including the tariff are reported in the tariff sensitivity table.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 33: *Complementarity Hypothesis: ITU Effectiveness Depends on Complements (excluding modelled BaTiS observations)*

	(1) Electricity	(2) Education	(3) Fixed BB	(4) Mobile BB	(5) Combined
ITU regulatory tracker (exporter, 0-1)	-1.0541	-2.2137**	-0.2927	-0.1405	-4.5277
	(2.0230)	(1.1183)	(0.2938)	(0.3193)	(3.5756)
ITU regulatory tracker (importer, 0-1)	-6.5769***	-1.1001**	-0.2589	-0.1845	-6.4915***
	(1.7825)	(0.5232)	(0.2206)	(0.2641)	(2.3228)
Electricity access (exporter, 0-1)	-0.8635				0.5461
	(1.1043)				(1.7450)
Electricity access (importer, 0-1)	-4.3033***				-2.5395
	(1.3214)				(1.6197)
ITU x Electricity (exporter)	1.4862				2.0622
	(2.0085)				(3.7298)
ITU x Electricity (importer)	6.9410***				5.4179**
	(1.8636)				(2.3517)
Log GDP (exporter)	0.8337***	0.9117***	0.7516***	0.7037***	0.8946***
	(0.0985)	(0.0919)	(0.1319)	(0.1274)	(0.0919)
Log GDP (importer)	0.5559***	0.5158***	0.5299***	0.4665***	0.4989***
	(0.0739)	(0.0719)	(0.1083)	(0.1122)	(0.0740)
Log population (exporter)	0.5719*	0.4980	0.3660	0.1446	0.5380
	(0.3434)	(0.3817)	(0.3197)	(0.3091)	(0.3692)
Log population (importer)	0.9126***	0.7332***	0.3919	0.3098	0.7797***
	(0.3050)	(0.2744)	(0.2723)	(0.2734)	(0.2583)
Baier-Bergstrand MTR correction (T1+T2-T3)	0.3691**	0.5004***	0.0423	-0.0458	0.4903***
	(0.1547)	(0.1516)	(0.1693)	(0.1555)	(0.1514)
Free trade agreement	0.1304**	0.1319***	0.0613	0.0539	0.1294***
	(0.0508)	(0.0408)	(0.0494)	(0.0499)	(0.0388)
Secondary enrollment (exporter, 0-1)		-2.4461***			-2.6541***
		(0.8861)			(0.9599)
Secondary enrollment (importer, 0-1)		-1.1230**			-1.1180***
		(0.5532)			(0.3923)
ITU x Secondary edu (exporter)		2.5174**			2.7474**
		(1.0876)			(1.1692)
ITU x Secondary edu (importer)		1.2894**			1.2805***
		(0.5561)			(0.3587)
Fixed broadband (exporter, 0-1)			-0.9810		
			(0.9789)		
Fixed broadband (importer, 0-1)			-1.7516***		
			(0.6509)		
ITU x Fixed BB (exporter)			2.2318**		
			(0.9392)		
ITU x Fixed BB (importer)			2.4214***		
			(0.6668)		
Mobile broadband (exporter, 0-1)				-0.3966	
				(0.2550)	
Mobile broadband (importer, 0-1)				-0.3537**	
				(0.1742)	
ITU x Mobile BB (exporter)				0.6030**	
				(0.2496)	
ITU x Mobile BB (importer)				0.6075***	
				(0.1892)	
Observations	920151	523307	872020	765778	519799
Pseudo R-squared	0.9322	0.9267	0.9313	0.9328	0.9267

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP, log population, and RTA-augmented remoteness of both partners (see text; the distance-only remoteness index is not identified alongside pair fixed effects). All variables on a 0-1 scale. Positive interactions indicate complementarity. Column 5 includes electricity and education together.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 34: *Africa Heterogeneity in Complementarity: Triple Interactions (excluding modelled BaTiS observations)*

Complement:	(1) Electricity access	(2) Secondary enrolment	(3) Fixed broadband	(4) Mobile broadband
ITU regulatory tracker (exporter)	-1.3158	-2.3533**	-0.2794	-0.1397
	(7.0500)	(1.1476)	(0.3026)	(0.3239)
ITU regulatory tracker (importer)	-4.8001***	-0.6572	-0.2020	-0.1448
	(1.4180)	(0.5061)	(0.2368)	(0.2727)
Complement (exporter)	-1.0452	-2.5553***	-0.9416	-0.3969
	(3.3428)	(0.9145)	(0.9812)	(0.2548)
Complement (importer)	-3.0690***	-0.7305	-1.6210**	-0.3441*
	(1.0870)	(0.5360)	(0.6304)	(0.1761)
ITU × Complement (exporter)	1.7543	2.6389**	2.2025**	0.5982**
	(7.0358)	(1.1201)	(0.9438)	(0.2505)
ITU × Complement (importer)	5.1463***	0.8567	2.2017***	0.5975***
	(1.4797)	(0.5216)	(0.6600)	(0.1918)
ITU × Africa (exporter)	1.5528	5.5213*	0.2743	0.2161
	(7.1199)	(3.1559)	(0.7248)	(0.5258)
ITU × Africa (importer)	-0.8369	-8.9765***	-1.0203	-0.9462
	(3.2034)	(2.1537)	(0.6676)	(0.5992)
Complement × Africa (exporter)	2.9850	5.5202*	-6.7489	0.1410
	(3.5097)	(3.0156)	(8.1527)	(0.4567)
Complement × Africa (importer)	-3.7695	-6.1968**	-23.6760*	-0.4284
	(3.8017)	(2.4944)	(13.8206)	(0.4608)
ITU × Complement × Africa (exporter)	-4.2423	-7.6047**	3.1029	-0.4011
	(7.1910)	(3.8560)	(9.3797)	(0.5233)
ITU × Complement × Africa (importer)	0.6313	8.6555***	26.6391	0.4798
	(3.9582)	(2.4476)	(17.4053)	(0.5347)
Observations	920151	523307	872020	765778
Pseudo R-squared	0.9323	0.9268	0.9313	0.9328

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP, log population, and RTA-augmented remoteness of both partners (see text; the distance-only remoteness index is not identified alongside pair fixed effects). All variables on a 0-1 scale. Each column includes the full set of constituent lower-order interactions, so the triple term measures the difference in the regulation-complement interaction for Africa; the Africa main effect is absorbed by the pair fixed effects. The marginal effect of regulation in Africa evaluated at the African mean of each complement is reported in the text. *Complement* denotes the variable named in the column heading (electricity access, secondary enrolment, fixed broadband or mobile broadband, all 0-1), so each row reports a different complement in each column.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 35: *Measurement Hypothesis: Testing Alternative Regulation Measures (excluding modelled BaTiS observations)*

	(1) C1+Depth	(2) C2+Depth	(3) C3+Depth	(4) C4+Depth	(5) Hetero	(6) DSTRI
ITU Cluster C1 (exporter, 0-1)	-2.5777**					
	(1.2945)					
ITU Cluster C1 (importer, 0-1)	-0.0374					
	(0.9751)					
ITU depth excl C1 (exporter, 0-3)	1.0037***					
	(0.2750)					
ITU depth excl C1 (importer, 0-3)	0.2412					
	(0.2497)					
ITU Cluster C2 (exporter, 0-1)		1.2392				
		(1.3942)				
ITU Cluster C2 (importer, 0-1)		1.2698				
		(0.8325)				
ITU depth excl C2 (exporter, 0-3)		0.3173				
		(0.3675)				
ITU depth excl C2 (importer, 0-3)		0.0505				
		(0.3910)				
ITU Cluster C3 (exporter, 0-1)			2.0666***			
			(0.5227)			
ITU Cluster C3 (importer, 0-1)			0.6432			
			(0.4324)			
ITU depth excl C3 (exporter, 0-3)			-0.7291*			
			(0.4209)			
ITU depth excl C3 (importer, 0-3)			-0.1606			
			(0.2915)			
ITU Cluster C4 (exporter, 0-1)				-1.3851**		
				(0.6156)		
ITU Cluster C4 (importer, 0-1)				-1.1013		
				(0.7769)		
ITU depth excl C4 (exporter, 0-3)				1.0941***		
				(0.4144)		
ITU depth excl C4 (importer, 0-3)				0.7001*		
				(0.3602)		
ITU regulatory tracker (exporter, 0-1)					0.4722*	
					(0.2558)	
ITU regulatory tracker (importer, 0-1)					0.2606	
					(0.2443)	
ITU heterogeneity index (0-1)					0.0785	
					(0.1482)	
Digital STRI, restrictiveness (exporter)						-0.0492
						(0.5759)
Digital STRI, restrictiveness (importer)						-0.2228
						(0.5433)
Observations	965571	965571	965571	965571	869241	152829
Pseudo R-squared	0.9323	0.9322	0.9323	0.9323	0.9318	0.9189

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP, log population, and RTA-augmented remoteness of both partners (see text; the distance-only remoteness index is not identified alongside pair fixed effects). All variables on a 0-1 scale. Columns 1-4: individual ITU clusters with the sum of the other three clusters as a depth control (Dur et al. 2014). Column 5: ITU heterogeneity index (bilateral regulatory differences). Column 6: DSTRI is on a RESTRICTIVENESS scale (higher = more restrictive), untransformed; a positive coefficient therefore indicates that more restrictive regimes are associated with more trade.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 36: *Measurement Hypothesis: Africa Heterogeneity in Regulation Components (excluding modelled BaTiS observations)*

	(1) C1 Authority	(2) C2 Mandate	(3) C3 Regime	(4) C4 Competition	(5) Hetero-geneity	(6) DSTRI
ITU cluster (exporter)	-2.5959**	1.2101	2.0486***	-1.3577**		
	(1.3090)	(1.3910)	(0.5406)	(0.6201)		
ITU cluster (importer)	-0.0331	1.1380	0.7566*	-1.0573		
	(0.9971)	(0.9637)	(0.4439)	(0.7779)		
Depth excl. cluster (exporter)	0.9993***	0.3215	-0.7270*	1.0826***		
	(0.2744)	(0.3722)	(0.4264)	(0.4159)		
Depth excl. cluster (importer)	0.2917	0.1278	-0.1732	0.7441**		
	(0.2647)	(0.4105)	(0.2949)	(0.3618)		
Cluster × Africa (exporter)	5.0146*	0.2692	-4.5335**	-1.3281		
	(2.6012)	(2.9946)	(2.0382)	(3.0917)		
Cluster × Africa (importer)	3.3147	2.0415	-6.2326**	0.8560		
	(3.5143)	(1.2996)	(2.8877)	(1.2061)		
Depth × Africa (exporter)	-2.9289**	-1.8222*	0.5997	-1.4740***		
	(1.4223)	(1.0528)	(0.7021)	(0.5492)		
Depth × Africa (importer)	-2.2053*	-1.7260**	2.8990	-2.1176*		
	(1.2237)	(0.7619)	(1.8040)	(1.1066)		
ITU regulatory tracker (exporter)					0.4708*	
					(0.2558)	
ITU regulatory tracker (importer)					0.2605	
					(0.2441)	
ITU heterogeneity index (bilateral)					0.0663	
					(0.1513)	
Heterogeneity × Africa (bilateral)					0.4351	
					(0.4460)	
Digital STRI, restrictiveness (exporter)						-0.0599
						(0.5767)
Digital STRI, restrictiveness (importer)						-0.2226
						(0.5398)
DSTRI × Africa (exporter)						2.7674**
						(1.3380)
DSTRI × Africa (importer)						0.3821
						(0.6027)
Observations	965571	965571	965571	965571	869241	152829
Pseudo R-squared	0.9323	0.9322	0.9324	0.9323	0.9318	0.9189

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP, log population, and RTA-augmented remoteness of both partners (see text; the distance-only remoteness index is not identified alongside pair fixed effects). All variables on a 0-1 scale. C1=Authority. C2=Mandate. C3=Regime. C4=Competition. Depth=sum of the other three clusters (Dur et al. 2014). Heterogeneity=bilateral regulatory differences. DSTRI is on a RESTRICTIVENESS scale (higher = more restrictive), untransformed; a positive coefficient therefore indicates that more restrictive regimes are associated with more trade. In columns 1-4, *ITU cluster* is the cluster named in the column heading (0-1) and *Depth excl. cluster* is the sum of the other three clusters (0-3). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 37: *Regulatory quality and digitally deliverable services trade, with and without ICT tariffs (BaTiS) (excluding modelled BaTiS observations)*

	ITU baseline			ITU × Africa		ITU × Gov. eff.	
	(1) Full sample	(2) Tariff sample	(3) With tariff	(4) No tariff	(5) With tariff	(6) No tariff	(7) With tariff
ITU reg. tracker (exp., 0-1)	0.4674*	0.4375*	0.3772	0.4265*	0.3626	-0.4611	-1.0955*
	(0.2752)	(0.2576)	(0.2673)	(0.2547)	(0.2654)	(0.4499)	(0.5919)
ITU reg. tracker (imp., 0-1)	0.2529	0.2816	0.2646	0.3352	0.3292	-1.2276***	-1.5496***
	(0.2702)	(0.2473)	(0.2431)	(0.2539)	(0.2485)	(0.3598)	(0.2953)
Log GDP (exp.)	0.8603***	0.8413***	0.8161***	0.8379***	0.8148***	0.8285***	0.7783***
	(0.0956)	(0.0990)	(0.1009)	(0.0996)	(0.1017)	(0.1036)	(0.1025)
Log GDP (imp.)	0.5523***	0.5463***	0.5260***	0.5295***	0.5139***	0.5682***	0.5172***
	(0.0757)	(0.0737)	(0.0813)	(0.0741)	(0.0807)	(0.0750)	(0.0813)
Log population (exp.)	0.5234	0.6372*	0.6314*	0.6439*	0.6397*	0.6302**	0.5358*
	(0.3490)	(0.3676)	(0.3726)	(0.3651)	(0.3717)	(0.3117)	(0.3126)
Log population (imp.)	0.7617**	0.9705***	0.9796***	1.0686***	1.0683***	0.7707**	0.7885***
	(0.3253)	(0.3340)	(0.3329)	(0.3159)	(0.3172)	(0.3076)	(0.2994)
Baier-Bergstrand MTR term	0.4041**	0.3833**	0.3488**	0.3706**	0.3408**	0.2876**	0.1897
	(0.1576)	(0.1533)	(0.1548)	(0.1504)	(0.1523)	(0.1367)	(0.1402)
Free trade agreement	0.1483***	0.1312***	0.1247***	0.1256**	0.1194**	0.0958*	0.0742
	(0.0487)	(0.0490)	(0.0470)	(0.0489)	(0.0475)	(0.0561)	(0.0499)
Log(1+ICT tariff), exp.			-1.3421		-1.3780		-3.0598**
			(1.3374)		(1.3326)		(1.5514)
Log(1+ICT tariff), imp.			-0.7150		-0.4375		-2.1100
			(1.2619)		(1.2239)		(1.3801)
ITU × Africa (exp.)				-1.7826*	-1.5635		
				(1.0759)	(1.0457)		
ITU × Africa (imp.)				-1.6264**	-1.6151**		
				(0.6851)	(0.6802)		
Gov. effectiveness (exp., 0-1)						-0.7756	-1.1746*
						(0.4805)	(0.6635)
Gov. effectiveness (imp., 0-1)						-1.6584***	-1.8776***
						(0.5260)	(0.5063)
ITU × Gov eff (exp.)						1.0847*	1.7225**
						(0.6563)	(0.8314)
ITU × Gov eff (imp.)						2.1988***	2.5700***
						(0.5076)	(0.4441)
Observations	965571	602846	602846	602846	602846	581800	581800
Pseudo R-squared	0.9322	0.9277	0.9277	0.9278	0.9278	0.9281	0.9281

Notes: PPML with country-pair and sector fixed effects. Standard errors two-way clustered by exporter and importer. Country-time-varying controls: log GDP and log population of both partners. Columns 1 and 2 exclude applied ICT goods tariffs and differ only in sample: column 2 is restricted to observations for which both partners' tariffs are available, so comparing columns 1 and 2 isolates the change in coverage and comparing columns 2 and 3 isolates the contribution of the control. Unlike the corresponding ITPD-E specifications, BaTiS contains no domestic flows, so the tariff enters directly rather than interacted with an international dummy and is identified from within-pair variation in applied tariffs over time. It is therefore not exposed to the constructed domestic trade residual that complicates interpretation of the ITPD-E estimate. Because most economies participate in the WTO Information Technology Agreement, residual variation in applied ICT tariffs is concentrated among non-participants and reflects broader differences in ICT openness alongside any price wedge. exp./imp. = exporter/importer.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 38: *Robustness to clustering: pair vs. two-way (exporter and importer) (excluding modelled BaTiS observations)*

	Fixed BB		Mobile BB		ITU × Africa		Triple interaction	
	(1) Pair	(2) Two-way	(3) Pair	(4) Two-way	(5) Pair	(6) Two-way	(7) Pair	(8) Two-way
Log(1+fixed BB pen.), exp.	0.1600***	0.1600**						
	(0.0417)	(0.0699)						
Log(1+fixed BB pen.), imp.	0.0059	0.0059						
	(0.0393)	(0.0649)						
Log(1+mobile BB pen.), exp.			0.0655***	0.0655				
			(0.0215)	(0.0400)				
Log(1+mobile BB pen.), imp.			0.0272	0.0272				
			(0.0194)	(0.0338)				
ITU reg. tracker (exp., 0-1)					0.4663***	0.4663*	-0.2294	-0.2294
					(0.1567)	(0.2742)	(0.2674)	(0.4797)
ITU reg. tracker (imp., 0-1)					0.2983**	0.2983	-1.0308***	-1.0308***
					(0.1365)	(0.2774)	(0.2954)	(0.3869)
ITU × Africa (exp.)					-1.5450***	-1.5450**	-0.4495	-0.4495
					(0.3273)	(0.6726)	(0.3662)	(0.7603)
ITU × Africa (imp.)					-1.3775***	-1.3775**	-4.6694***	-4.6694***
					(0.3454)	(0.6107)	(1.2549)	(1.3456)
Gov. effectiveness (exp., 0-1)							-0.4605	-0.4605
							(0.3040)	(0.4877)
Gov. effectiveness (imp., 0-1)							-1.5583***	-1.5583***
							(0.3302)	(0.5123)
ITU × Gov eff (exp.)							0.7751**	0.7751
							(0.3857)	(0.6525)
ITU × Gov eff (imp.)							1.9569***	1.9569***
							(0.3978)	(0.5126)
Gov eff × Africa (exp.)							4.2743***	4.2743**
							(0.9603)	(1.9450)
Gov eff × Africa (imp.)							-5.1802***	-5.1802***
							(1.7106)	(1.7276)
ITU × Gov eff × Africa (exp.)							-3.7892***	-3.7892*
							(1.2803)	(2.2127)
ITU × Gov eff × Africa (imp.)							6.3294***	6.3294***
							(2.1810)	(2.1839)
Observations	999941	999941	785267	785267	965571	965571	879206	879206

Notes: Pair = clustered by country-pair. Two-way = clustered by exporter and importer (Egger and Tarlea 2015). Point estimates are identical within each pair of columns; only standard errors differ. The triple-interaction columns use the same full constituent set as the main implementation-gap table. exp./imp. = exporter/importer; BB = broadband; pen. = penetration.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

E Additional tables from the connectivity model

This appendix reports the estimates underlying Section 4 in full. It is organised in three parts. Section E.1 reports the adoption system that tests Proposition 1, first in full and then in the specifications that ask whether the flat African price relation holds throughout the price distribution. Section E.2 reports the two supply-side relationships of the model, the investment condition and the pricing bound, neither of which is separately identified. Section E.3 reports two further checks that no claim in the main text depends on: the cross-price parameter and the composition of the fixed usage gap.

E.1 The adoption system

Table 9 in the main text reports the price and coverage coefficients on which Proposition 1 turns, together with the complements that shift willingness to pay. Table 39 reports all four columns of that system in full, including the interaction of every regressor with the fixed-technology indicator and the fit statistics.

Three features are worth drawing out. First, the interactions with the fixed-technology indicator are what make the stacked design informative: because the two adoption equations are estimated jointly, each fixed–mobile difference is a single coefficient with a valid clustered standard error, rather than a comparison across two separately estimated equations for which no covariance is available.

Second, the pattern in those interactions extends Proposition 1 beyond the price margin. Under availability rationing, adoption is set by coverage, so nothing on the demand side should move fixed adoption—not only price, but the complements as well. The memorandum rows show that this is broadly what the estimates deliver, and they do so in every column. Electricity access carries a large and highly significant coefficient for mobile, between 1.76 and 2.56 across the four specifications, but the fixed-technology interaction is of almost exactly the opposite magnitude and is significant at one per cent in three columns and at five in the fourth, leaving implied fixed coefficients of -0.24, -0.29, -0.14 and -0.20. The implied fixed coefficients on secondary enrolment and government effectiveness are likewise close to zero, between -0.14 and -0.02, against mobile coefficients of up to 0.27 and 0.58. Only the electricity interaction is individually significant, so the pattern across the remaining complements is suggestive rather than decisive, but every one of them points the same way as the price result, and the consistency across specifications is itself informative.

Third, the ITU Regulatory Tracker behaves differently from the other complements. Its implied fixed coefficient, between 0.52 and 0.59, is the largest of the set and is close to its mobile coefficient rather than offsetting it. That is what one would expect if regulation operates on the supply side, where it shifts the coverage that rations fixed adoption, rather than through willingness to pay.

Table 40 asks whether the flat African fixed price–adoption relation documented in Section 4.3 holds throughout the African price distribution, or only on average. The distinction matters for policy. If African fixed broadband were simply priced beyond reach, the relation should steepen at the bottom of the price range, where access is most affordable; a price cut would then move adoption once prices fell far enough. If instead price is not the operative margin, the relation should be flat everywhere.

Table 39: *The stacked adoption system in full*

	(1) Baseline	(2) USD price	(3) Africa	(4) Income
Dependent variable: ln(1+ *subscriptions per 100 inhabitants*)				
Direct terms (mobile)				
Coverage	0.061*** (0.022)	0.064*** (0.022)	0.067*** (0.025)	0.057*** (0.021)
Own price (% GNI)	−0.156*** (0.050)		−0.165*** (0.061)	−0.030 (0.050)
Own price (USD)		−0.102*** (0.039)		
Other technology's price	−0.018 (0.038)	−0.023 (0.040)	−0.014 (0.041)	−0.026 (0.034)
Electricity access	2.348*** (0.689)	2.561*** (0.700)	2.480*** (0.716)	1.758** (0.714)
Secondary enrolment	0.223 (0.358)	0.268 (0.358)	0.235 (0.357)	0.144 (0.359)
ITU Tracker (0–1)	0.716* (0.367)	0.726* (0.375)	0.697* (0.371)	0.715** (0.348)
Gov. effectiveness (0–1)	0.511* (0.288)	0.576* (0.294)	0.524* (0.289)	0.404 (0.275)
DDS content p.c., $t-2$	0.008 (0.185)	0.011 (0.183)	0.000 (0.188)	0.006 (0.180)
ln(GDP per capita)	0.173** (0.081)	0.235*** (0.085)	0.168** (0.078)	0.114 (0.084)
Interactions with the fixed-technology indicator				
Fixed × coverage	0.079 (0.052)	0.074 (0.053)	0.154** (0.066)	0.086* (0.051)
Fixed × own price	0.144** (0.056)		0.179*** (0.067)	0.008 (0.062)
Fixed × price (USD)		0.072 (0.045)		
Fixed × other price	0.008 (0.049)	0.017 (0.049)	−0.005 (0.050)	0.016 (0.048)
Fixed × electricity	−2.588*** (0.858)	−2.845*** (0.862)	−2.619*** (0.937)	−1.956** (0.904)
Fixed × enrolment	−0.339 (0.455)	−0.380 (0.454)	−0.373 (0.440)	−0.264 (0.456)
Fixed × ITU	−0.144 (0.540)	−0.136 (0.543)	−0.180 (0.539)	−0.158 (0.519)
Fixed × gov. eff.	−0.575 (0.393)	−0.647 (0.400)	−0.544 (0.395)	−0.454 (0.378)
Fixed × DDS content	0.106 (0.197)	0.086 (0.194)	0.075 (0.202)	0.126 (0.191)
Africa and income interactions				
Africa × own price			0.029 (0.113)	
Africa × fixed × price			−0.083 (0.122)	
Africa × coverage			−0.027 (0.050)	
Africa × fixed × coverage			−0.167 (0.105)	
Own price × y_c				0.119*** (0.034)
Fixed × price × y_c				−0.126*** (0.041)
Constant	−0.542 (0.908)	−1.121 (0.916)	−0.575 (0.872)	0.248 (0.906)
Memorandum: implied coefficients for fixed broadband				
Own price	−0.012 (0.032)	−0.030	0.014 (0.042)	−0.022
Coverage	0.140*** (0.047)	0.138	0.221	0.143
Electricity access	−0.241	−0.285	−0.139	−0.198
Secondary enrolment	−0.117	−0.112	−0.139	−0.120
ITU Tracker	0.572	0.590	0.517	0.557
Gov. effectiveness	−0.064	−0.072	−0.020	−0.049
DDS content p.c., $t-2$	0.113	0.097	0.075	0.132
Other technology's price	−0.010	−0.006	−0.019	−0.011
Observations	1,968	1,968	1,968	1,968
Countries	146	146	146	146
Within R^2	0.190	0.180	0.203	0.214
Model F	5.48***	5.39***	5.75***	5.24***
Root MSE	0.191	0.192	0.190	0.188

Notes: The four columns of Table 9, reported in full. Fixed and mobile adoption equations are stacked over technology, with country-by-technology and year-by-technology effects absorbed (288 and 18 categories) and standard errors clustered by country; 22 singleton observations are dropped. Subscriptions, coverage, both prices and DDS content per capita enter as $\ln(1+x)$, so the price and coverage coefficients are elasticities; electricity access, secondary enrolment and the two institutional indices enter in levels. ln(GDP per capita) carries a coefficient common to the two technologies and is therefore not interacted; every other regressor is. In column 2 the price-to-GNI ratio is replaced by the price in USD. In column 3 the Africa-by-fixed level term is collinear with the country-by-technology effects and is dropped; in column 4 the centred income term y_c is likewise dropped, so the reported price coefficients are evaluated at mean income. The memorandum adds each direct coefficient to its fixed-technology interaction, using the same rounding as Table 9; standard errors are reported where they were computed as linear combinations. Under availability rationing these are not estimates of demand parameters, since quantity is set by coverage rather than by the intersection of supply and demand. The model F tests the joint significance of the reported slopes, with $(17, 145)$, $(17, 145)$, $(21, 145)$ and $(19, 145)$ degrees of freedom; all four have $p < 0.001$.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The answer is that the relation is flat throughout, and where it is not flat it moves in the direction opposite to the affordability reading. Column 1 lets the price slope differ across quartiles of the African price distribution, with non-African fixed observations as the omitted category; the memorandum rows add the omitted category's slope to each interaction. The quartile cut points are 2.1, 3.7 and 4.4 on the $\ln(1+x)$ scale on which price enters the regression, so the exercise spans a wide range of affordability. The four implied slopes are +0.044 (0.061), −0.076 (0.050), −0.080 (0.041) and −0.034 (0.028). None is significant at five per cent; the third is marginal, at $p = 0.053$.

The four slopes are not, however, identical: the hypothesis that they are equal is rejected, $F(3, 145) = 5.14$, $p = 0.002$. This is worth stating plainly, because it is the one result in this section that a purely flat reading does not predict. What the rejection does not deliver is the pattern affordability requires. That reading predicts the steepest—most negative—slope in the cheapest quartile, where a price cut should bite hardest. The cheapest quartile is instead the one positive slope of the four, and the ordering across quartiles is non-monotone. The quartile slopes therefore differ from one another, but not in a way that identifies a segment of the African price distribution in which adoption responds to price.

Column 2 is the smooth counterpart, estimated on African fixed observations alone so that the result does not depend on where the quartile cuts fall. The linear term is −0.066 (0.066) and the quadratic +0.009 (0.011), neither significant, and the specification as a whole is not significant, $F(9, 30) = 1.33$, $p = 0.26$. That column rests on 167 observations and 31 country clusters and should be read as corroborative only. Coverage is the variable that moves fixed adoption in the larger column 1 sample, where it enters at 0.157 (0.041), significant at one per cent. Within African fixed markets, quantity moves with coverage and does not move with price, at any price.

E.2 The supply block

The next two tables report the attempt to estimate the two supply-side relationships of the model separately, and are the basis for the conclusion in Section 4.3 that this cannot be done with the available instruments. They are reported because a negative identification result is itself informative: the investment condition and the pricing bound involve the same two variables, price and coverage, with opposite predicted slopes, so a single regression of one on the other cannot distinguish them.

Table 41 takes the investment condition (9), which predicts that coverage rises with the operating margin. Marginal cost is unobserved, so price proxies for the margin, and the predicted coefficient is therefore *positive*. It is negative in every column, and significantly so in four of the five; only the tariff-instrumented column 4 is not. Columns 2–4 rule out the obvious explanations in turn—omitted income while the price variable is a share of GNI, the income normalisation itself, and the endogeneity of price—and none of them reverses the sign. The first-stage statistics in columns 2 and 4, 1.78 and 0.48, are far below any conventional threshold, which is the more fundamental problem: the instrument set has no power for this relationship.

Table 42 takes the other direction, the pricing bound (13), which holds in the availability-rationed regime: the operator prices at the willingness to pay of the marginal passed household, so extending coverage brings lower-valuation households into the served population and the price falls. The fixed coefficient, −0.955 (0.209), has the predicted sign and is significant at one per cent. But the mechanism is specific to fixed broadband, and column 2 shows that the mobile placebo returns

Table 40: *Is the African fixed price–adoption relation flat throughout?*

	(1) African price quartiles	(2) Quadratic, Africa only
Dependent variable: fixed-broadband adoption		
Coverage	0.157***	−0.022
	(0.041)	(0.081)
Own price (% GNI)	−0.008	−0.066
	(0.046)	(0.066)
Own price squared		0.009
		(0.011)
Own price × African quartile 1 (cheapest)	0.052	
	(0.074)	
Own price × African quartile 2	−0.068	
	(0.064)	
Own price × African quartile 3	−0.072	
	(0.058)	
Own price × African quartile 4 (dearest)	−0.026	
	(0.054)	
Secondary enrolment (share)	−0.143	−0.157
	(0.194)	(0.607)
Electricity access (share)	−0.189	0.222
	(0.479)	(0.896)
ITU Regulatory Tracker (0–1)	0.661*	−1.467**
	(0.350)	(0.688)
Government effectiveness (0–1)	−0.059	−0.214
	(0.202)	(0.762)
DDS content per capita, $t-2$	0.146*	0.098
	(0.075)	(0.215)
ln(GDP per capita)	0.026	−0.054
	(0.087)	(0.263)
Constant	0.627	2.064
	(1.140)	(1.759)
Memorandum: implied slope within each African quartile		
Quartile 1 (cheapest)	0.044 (0.061)	
Quartile 2	−0.076 (0.050)	
Quartile 3	−0.080 (0.041)	
Quartile 4 (dearest)	−0.034 (0.028)	
Observations	1,019	167
Countries	146	31
Within R^2	0.109	0.090
Model F	3.71***	1.33

Notes: Fixed-broadband observations only, with country and year effects and standard errors clustered by country. Column 1 lets the price slope differ across quartiles of the African price distribution, with non-African observations as the omitted category; the memorandum rows add the omitted category's slope to each interaction. Column 2 is the smooth counterpart estimated on African observations alone. A steeper slope in the cheapest quartile would indicate that adoption responds to price where fixed access is affordable, which is the prediction of the reading in which African fixed broadband is merely priced beyond reach. Income is controlled throughout, since the price variable is expressed as a share of GNI per capita. Subscriptions, coverage and price enter as $\ln(1+x)$; the quartile cut points (2.1, 3.7 and 4.4) are on that scale. The four quartile slopes are jointly different from one another, $F(3, 145) = 5.14$, $p = 0.002$, but not in the order the affordability reading requires. The model F has $(12, 145)$ degrees of freedom in column 1 and $(9, 30)$ in column 2.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 41: *Coverage and the operating margin*

	(1) Mobile, no income	(2) Mobile, +income	(3) Mobile, USD price	(4) Mobile, tariff IV	(5) Fixed (proxy)
Mobile price, % GNI	-2.143^{***}	-2.451^{***}		-6.891	
	(0.738)	(0.827)		(10.150)	
Mobile price, USD per month			-2.030^{***}		
			(0.612)		
Fixed price, % GNI					-1.127^{***}
					(0.411)
ln(GDP per capita)		-0.959	0.852	-1.524	-0.598^{*}
		(0.931)	(0.840)	(2.792)	(0.308)
ln(Population density)	-3.444	-5.107	-3.639	-15.672	0.960
	(2.873)	(3.491)	(3.354)	(22.367)	(1.227)
Electricity access (share)	-1.415	-2.013	-0.285	-14.988	-1.945
	(4.374)	(4.709)	(3.828)	(30.154)	(1.662)
ITU Regulatory Tracker (0–1)	4.593	4.844	4.915	-4.352	5.634^{**}
	(4.520)	(4.976)	(4.663)	(18.155)	(2.386)
Government effectiveness (0–1)	2.489	2.438	4.401	-12.048	5.682^{**}
	(5.254)	(5.733)	(5.450)	(27.835)	(2.373)
ITU Tracker × Gov. effectiveness	-6.018	-6.020	-7.760	11.808	-6.064^{**}
	(6.226)	(6.859)	(6.820)	(31.723)	(2.859)
Observations	620	620	620	813	629
Kleibergen–Paap first-stage F		1.78		0.48	

Notes: Dependent variable is population coverage in columns 1–4 and the fixed coverage proxy in column 5. Country and year effects throughout, standard errors clustered by country. The investment condition predicts a *positive* price coefficient: a higher achievable margin supports a wider network. Marginal cost is not observed, so price proxies for the margin. Column 1 reproduces a specification that omits income while the price variable is a share of GNI per capita; columns 2–4 correct this by controlling for income, by using the basket in absolute dollars, and by instrumenting price with applied ICT goods tariffs alone, the only instrument plausibly excluded from the investment condition. Column 5 uses the fixed coverage proxy, which counts households with internet access of any kind and is therefore an adoption measure; its regulatory coefficients follow the sign pattern of the price equation rather than of the coverage equation, which is what that limitation predicts. The post-cable indicator was collinear with the country effects in every column and is omitted.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

the same sign at the same significance, -0.572 (0.126), even though mobile prices are set on the demand curve and the pricing bound should not apply. The placebo therefore fails, and the fixed coefficient cannot be read as an estimate of w'. We report the price–coverage association descriptively and draw no structural conclusion from it.

E.3 Further checks

The last two tables are reported for completeness. No claim in Section 4 depends on either.

Table 43 estimates the cross-price parameter η_{FM}, which asks whether the two technologies are substitutes in adoption: a positive coefficient on the other technology's price would mean that households treat mobile as a substitute for a fixed connection. This bears on the mobile-first reading of Stylized Fact 1, under which Africa's mobile lead suppresses fixed demand. The estimates do not support a clean answer. The cross-price terms in the fixed and mobile equations carry opposite signs (-0.103 in column 1 against $+0.140$ in column 3), which a well-behaved demand system should

Table 42: *Does extending coverage lower the price?*

	(1) Fixed	(2) Mobile (placebo)
Fixed coverage proxy (instrumented)	-0.955^{***}	
	(0.209)	
4G population coverage (instrumented)		-0.572^{***}
		(0.126)
ln(GDP per capita)	0.152	−0.335
	(0.170)	(0.360)
ln(Population density)	1.978^{***}	-2.445^{**}
	(0.588)	(1.059)
Electricity access (share)	0.000	0.000
	(1.250)	(1.515)
ITU Regulatory Tracker (0–1)	2.093^{***}	1.233^{***}
	(0.634)	(0.338)
Government effectiveness (0–1)	−0.022	−1.070
	(0.437)	(0.658)
Observations	1,019	949

Notes: Dependent variable is the broadband price as a share of GNI per capita. Country and year effects throughout, standard errors clustered by country. Coverage is instrumented with cable-landing geography, and income is controlled in both columns. Under availability rationing the operator prices at the willingness to pay of the marginal passed household, so price falls as coverage extends and $w' < 0$. The prediction applies to fixed broadband; column 2 is a placebo, since mobile price is set on the demand curve and the pricing bound does not apply there. The placebo returns the same sign at the same significance, so the fixed coefficient is not read as an estimate of w' and the association is reported descriptively. The Kleibergen–Paap statistic was not returned for either specification, so instrument strength here is unverified, which is a further reason for the descriptive reading.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

not produce, and the Africa interaction in column 2 is insignificant. We read this as evidence that the parameter is not identified here rather than as evidence on substitution either way.

Table 44 asks what the fixed usage gap of Stylized Fact 2 is made of. The dependent variable counts households connected by something other than fixed broadband, so it is predominantly a measure of mobile connection. If the gap were mobile substitution, mobile subscriptions should enter positively and the mobile price negatively. Mobile subscriptions do enter positively in the pooled column, at 0.241 (0.127), but the mobile price is insignificant, and neither holds in the African subsample. The African subsample has only 148 observations, so these results are suggestive at best; we do not read them as settling whether the usage gap reflects substitution or infrastructure.

Table 43: *The cross-price parameter η_{FM}*

	(1) Fixed, pooled	(2) Fixed, Africa interacted	(3) Mobile
Fixed coverage proxy (instrumented)	0.316*	0.256*	
	(0.165)	(0.146)	
4G population coverage (instrumented)			0.200
			(0.131)
Fixed price, % GNI	−0.154	−0.185	−0.261
	(0.226)	(0.169)	(0.322)
Mobile price, % GNI	−0.103	−0.117	0.140
	(0.217)	(0.147)	(0.328)
Content per capita, $t-2$	0.101	0.070	0.000
	(0.123)	(0.128)	(0.149)
ITU Regulatory Tracker (0–1)	0.398	0.577	0.472
	(0.530)	(0.462)	(0.672)
Government effectiveness (0–1)	−0.286	−0.041	1.049**
	(0.368)	(0.214)	(0.527)
Africa × coverage		0.706*	
		(0.402)	
Africa × fixed price		0.554	
		(0.511)	
Africa × mobile price		0.477*	
		(0.265)	
Africa × content		0.601	
		(0.638)	
Memorandum: implied cross-price effect			
Africa		0.360	
Outside Africa	−0.103	−0.117	
Observations	629	629	620

Notes: Dependent variable is fixed-broadband adoption in columns 1–2 and mobile adoption in column 3. Country and year effects throughout, standard errors clustered by country; coverage and both prices are instrumented. A positive coefficient on the other technology's price means the two are substitutes. Column 2 tests whether Africa differs; column 3 checks sign symmetry from the mobile equation, and the two cross-price terms carry opposite signs, which a well-behaved demand system should not produce. Schooling and electricity are included and suppressed. Reported for completeness; no claim in Section 4 depends on this parameter.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 44: *Is the fixed usage gap mobile substitution?*

	(1) All	(2) Africa	(3) Non-Africa
Mobile subscriptions per 100	0.241*	0.062	0.259
	(0.127)	(0.136)	(0.166)
Mobile price, % GNI	−0.113	−0.106	−0.042
	(0.091)	(0.116)	(0.121)
Fixed price, % GNI	−0.147**	−0.058	−0.218**
	(0.067)	(0.086)	(0.096)
Secondary enrolment (share)	0.907	−1.729	1.017
	(0.912)	(1.188)	(1.027)
Electricity access (share)	1.630	−1.411	3.747
	(1.290)	(1.253)	(2.483)
ln(GDP per capita)	0.010	−0.363	−0.013
	(0.373)	(0.689)	(0.414)
ITU Regulatory Tracker (0–1)	2.605**	0.028	2.895**
	(1.127)	(2.122)	(1.334)
Government effectiveness (0–1)	1.071*	4.326**	0.466
	(0.630)	(1.689)	(0.662)
Content per capita, $t-2$	−0.429	−0.135	−0.498
	(0.373)	(0.276)	(0.586)
Constant	−0.514	6.380	−2.282
	(3.156)	(5.130)	(3.701)
Observations	712	148	564

Notes: The dependent variable is the household-adjusted fixed usage gap, which counts households connected by something other than fixed broadband and is therefore predominantly a measure of mobile connection. Country and year effects throughout, standard errors clustered by country. A substitution reading predicts a positive coefficient on mobile subscriptions and a negative one on the mobile price; a pure-infrastructure reading predicts neither. The African subsample is thin and the results for it are suggestive only.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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