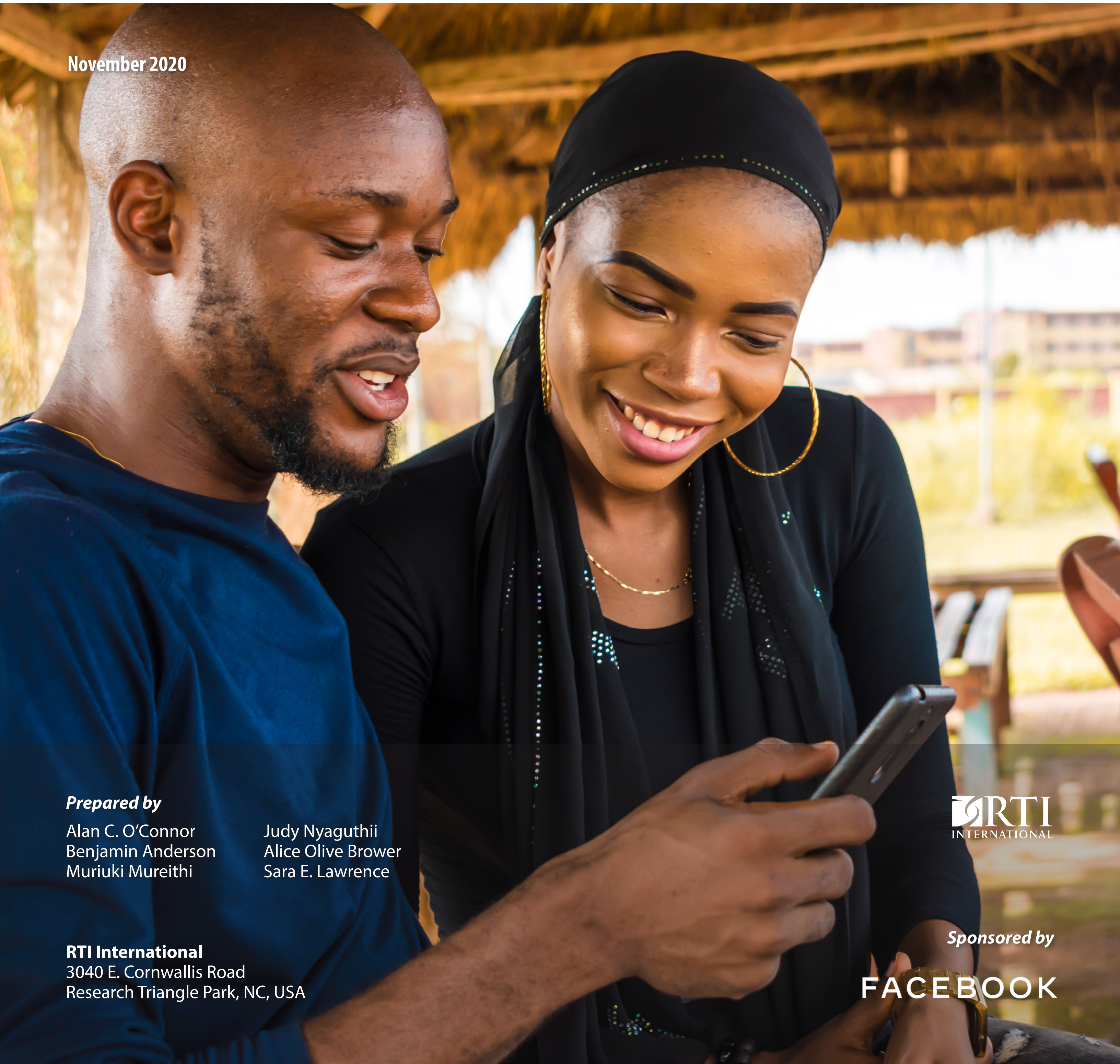
Economic Impacts of Submarine Fiber Optic Cables and Broadband Connectivity in Kenya

Working Paper 0214363.202.2



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Prepared by

Alan C. O'Connor
Benjamin Anderson
Muriuki Mureithi
Judy Nyaguthii
Alice Olive Brower
Sara E. Lawrence

RTI International
3040 E. Cornwallis Road
Research Triangle Park, NC, USA

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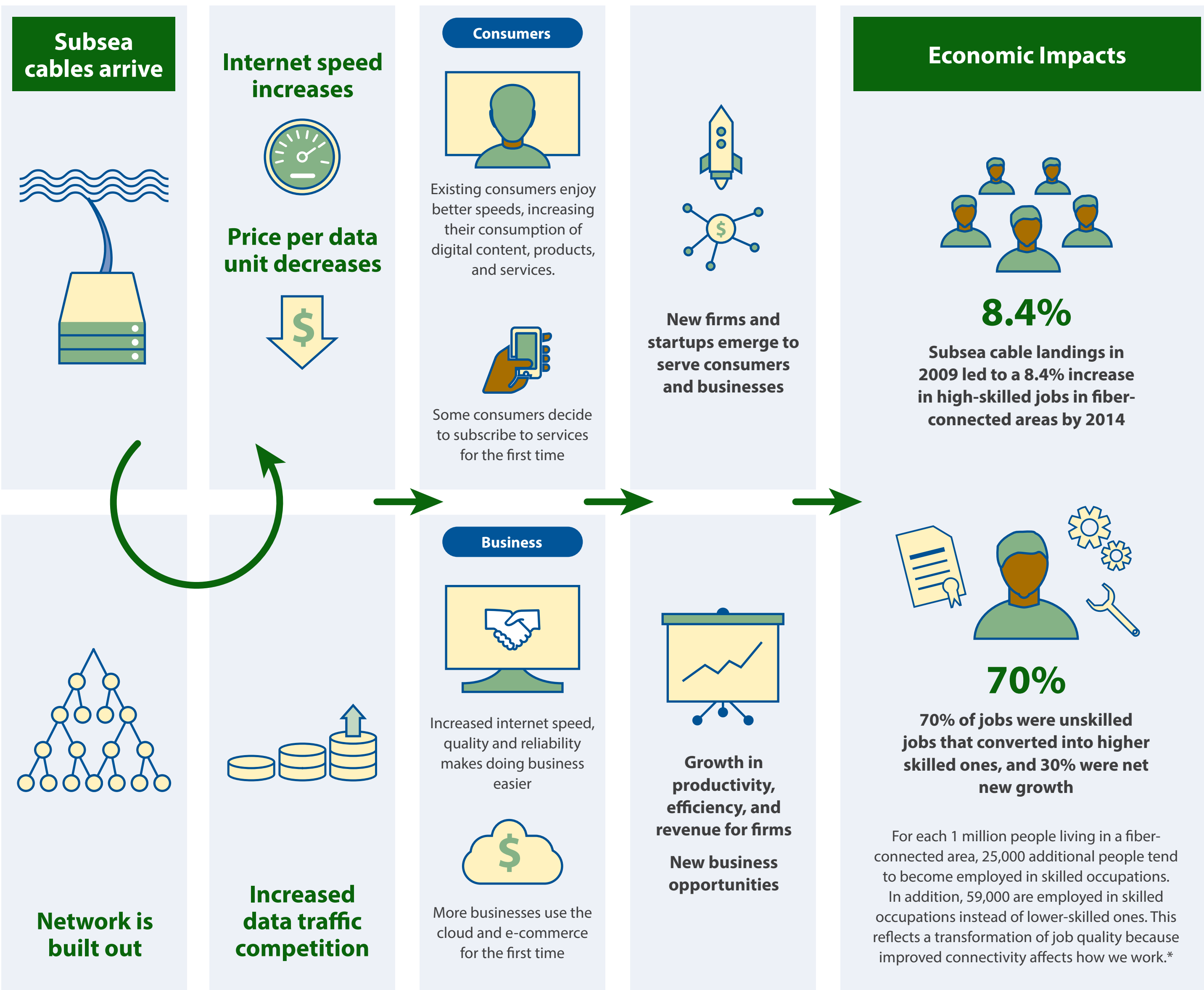
HOW DO SUBSEA CABLES GENERATE ECONOMIC IMPACT?

Subsea cables are the global backbone of the Internet, connecting people, businesses, and economies around the world. They connect us to the cloud, deliver streaming video, and increase efficiency and productivity for business. Subsea cables' importance is all the more apparent during the Covid19 pandemic when many of us have switched to working from home, remote learning, and online gaming and entertainment.

We studied the economic impacts from subsea cables that arrived in Kenya in 2009 (e.g., TEAMS) to understand how they changed the economy. Increases in Internet usage and decreases in costs because of subsea cables have led to development impacts and contributed to Kenya's economic growth.



* The results indicate that the economic growth catalyzed by subsea cables was concentrated in urban areas. There have been increases in the number of jobs available there, and these jobs are higher skilled than the ones available in the past. However, the economic transformation was not detectable in national-level employment or GDP per capita data by 2014 because of the overall characteristics and structure of Kenya's economy. Our results are an early signal of growing national impact.

Download the full report at rti.org/subsea-cables-africa

Alan C. O'Connor, Senior Director, Center for Applied Economics & Strategy | oconnor@rti.org, +1.919.541.8841

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Table of Contents

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1. Overview

This study explores the economic impact of the internet connectivity delivered by submarine fiber optic cables ("subsea cables") on Kenya. Subsea cables are the global backbone of the internet, connecting people, businesses, and economies around the world (Figure 1).[1,2]

The importance of connectivity to economic growth is well-established—as underscored by our collective experience during the COVID-19 pandemic—but rigorous studies have not been conducted for many countries.[3,4,5] This study is one in a series our team prepared about how improvements in international data connectivity have generated economic growth for countries in Africa.[6] We look in particular at the impact of the TEAMS (The East African Marine System), a cable that was landed by a public-private partnership between the Kenyan government, telecom players, and investors.

Often referred to as the "Silicon Savannah" and renowned for the mobile payment platform M-PESA, Kenya has one of the most dynamic ICT sectors in Africa. It has a vibrant ecosystem of tech start-ups, is home to telecom-innovator Safaricom, and has multiple firms competing in each segment of its liberalized telecommunications market. According to estimates from Kenya's National Bureau of Statistics, the ICT sector on its own contributed more than 1% of GDP in 2018, growing by 9.6% in the third quarter of the same year.

In brief, our analysis found that recent subsea cable landings and the resulting boost in connectivity had a net employment impact of +2.5%. Notably, there was a shift towards higher skilled jobs (gains of 8.4%) away from lower skilled ones (losses of 5.9%), especially in cities like Nairobi and Mombasa (Table 1). This reflects a transformation of jobs because improved connectivity affects how we work.

We observed a 3,800% increase in financial services exports, an indicator of impact because finance is one of the most ICT-intensive industries. Overall, firms are much more likely to use email for business, engage in e-commerce, and leverage cloud services.

Kenyan internet experts interviewed concurred. They described how increases in usage and decreases in cost have led to development impacts.

Our results focus on the specific impact of subsea cables, controlling for economic conditions, population, technology, and other relevant factors. Herein we review our analysis approach, results, and experts' perspectives on the trends and priorities that are important to keep in mind as efforts progress to derive further economic development value out of data connectivity.

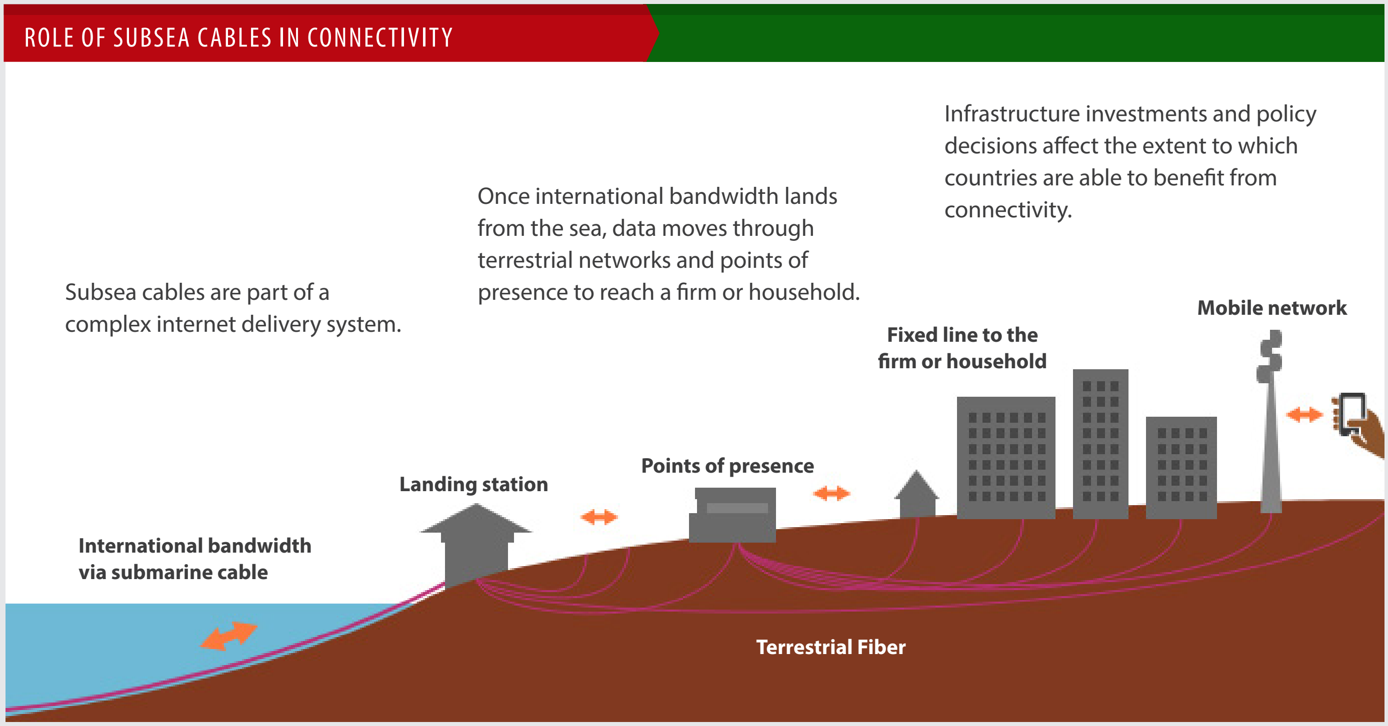
Table 1. **Key Takeaways: The Economic Impact of Subsea Cables on Kenya**

INDICATOR	TIME PERIOD	OUTCOME
Employment growth in connected areas	2008—2014	+ 2.5 net increase in likelihood of being employed • 8.4% increase in the likelihood of being employed in a skilled occupation • 5.9% decrease in the likelihood of being employed in a low skill occupation This means that, for every 1 million people, we see 25,000 new skilled jobs and the transformation of 59,000 jobs to higher skilled ones
National financial sector growth	2009—2013	3,800% increase in financial services exports

Source: Authors' estimates.

1 Clark, K. 2019. *Submarine Telecoms Industry Report, 7th Edition*. Submarine Telecoms Forum.
2 Brake, D. 2019. *Submarine Cables: Critical Infrastructure for Global Communications.* Information and Technology Foundation.
3 Hjort, J, Poulsen, J. 2019. The Arrival of Fast Internet and Employment in Africa. *American Economic Review*, 109(3): 1032-1079.
4 Minges, M. 2015. Exploring the Relationship between Broadband and Economic Growth. WDR 2016 Background Paper; World Bank, Washington, DC.
5 Khalil, M., Dongier, P., & Zhen-Wei Qiang, C. 2009. *Information and Communications for Development: Extending Reach and Increasing Impact*. World Bank.
6 Other countries included in this series are the Democratic Republic of Congo, Nigeria, Mozambique, South Africa, and Tanzania.

Figure 1. Role of Subsea Cables in Internet Connectivity



2. Kenya Country Profile

Kenya is Africa's 7th largest country by population (about 50 million) and 6th largest by GDP. It is a diverse society with 42 recognized ethnic communities, most of which have their own distinct languages and dialects.

About three quarters of Kenyans live in rural areas. Although only one quarter live in cities, particularly Nairobi and Mombasa, the urban population is growing at a rate of roughly 4% per year. This is twice the growth rate for rural areas, reflecting a broad trend towards urbanization.

Kenya's gross domestic product (GDP)—the most common measure of the value of all goods and services produced by a country—was $95.5 billion (nominal terms) in 2019 (Table 2). GDP per capita was $1,817. The economy is growing briskly, with real growth rates averaging more than 5% per year over the past decade, according to the International Monetary Fund. IMF also believes that the economy is larger than official estimates after accounting for informal activity. It estimated that the informal sector was equivalent to roughly 30% of official GDP between 2010 and 2014.[7]

Agriculture is the largest sector, followed closely by services. Kenya is a leading exporter of tea (accounting for 19% of global tea exports), coffee, and fresh cut flowers. Other important sectors are transportation and storage, finance and insurance, and real estate. Key figures describing Kenya are presented in Table 2.

Another way to look at Kenya's GDP is to take into consideration purchasing power parity (PPP). PPP accounts for differing price levels for comparable expenditure categories between countries. By applying PPP one can assess, both between countries and over time, real year-on-year changes and economic trends based on actual living standards. The current base year for PPP is 2011.

7 International Monetary Fund. 2017. Regional Economic Outlook: Sub-Saharan Africa, Restarting the Growth Engine. Washington D.C.: International Monetary Fund.

Table 2. Key Indicators for Kenya's Population and Economy

INDICATOR		VALUE	YEAR
Population		50 million people	2019[b]
Literacy Rate		82% of population aged 15+	2018[b]
Primary education completing rate		51% of population aged 25+	2010[b]
Poverty rate		37% of population below WB poverty line of 1.90 USD PPP/day	2015[b]
GDP, nominal USD	• Total • Per capita	95.5 billion 1,817	2019[b]
GDP, nominal KES	• Total • Per capita	9.7 trillion 185,270	2019[b]
GDP, purchasing power parity	• Total • Per capita	154,billion (2011 USD PPP) 3,090 (2011 USD PPP)	2017[a]
GDP growth rate		6.32	2018[b]
Unemployment		9.3% of labor force	2018[b]

Sources: [a]Penn World Table.[8] [b]The World Bank.[9]

Through the lens of PPP, Kenya's economy is the equivalent of $154 billion (2011 USD PPP) with a per capita GDP of $3,090. Later, we will use the PPP method of quantifying the Kenyan economy to generate our results, enabling impacts to be interpreted directly as improvements in living standards relative to different points in the past.

Kenya is connected to five active submarine cables that all land in the port city of Mombasa, Kenya's oldest and second-largest city (Table 3). To date, the most significant of these is the TEAMS (The East Africa Marine System) cable, a public-private partnership launched by the national government.[10] Recent cable landings include DARE and Facebook also announced 2Africa, which will ultimately encircle the continent.

Table 3. Subsea Cables Landing in Kenya

CABLE	DESIGN CAPACITY (TBPS)	LOCAL LANDING STATION(S)	READY FOR SERVICE YEAR
The East African Marine System (TEAMS)	5.2	Mombasa	2009
East Africa Submarine Cable System (EASSy)	11.8	Mombasa	2010
Lower Indian Ocean Network 2 (LION2)	1.28	Mombasa	2012
SEACOM/TATA TGN-Eurasia	4.2	Mombasa	2009
DARE 1	36	Mombasa	2020
PEACE (announced)	TBA	Mombasa	2021
2Africa (announced)	180	Mombasa	2023

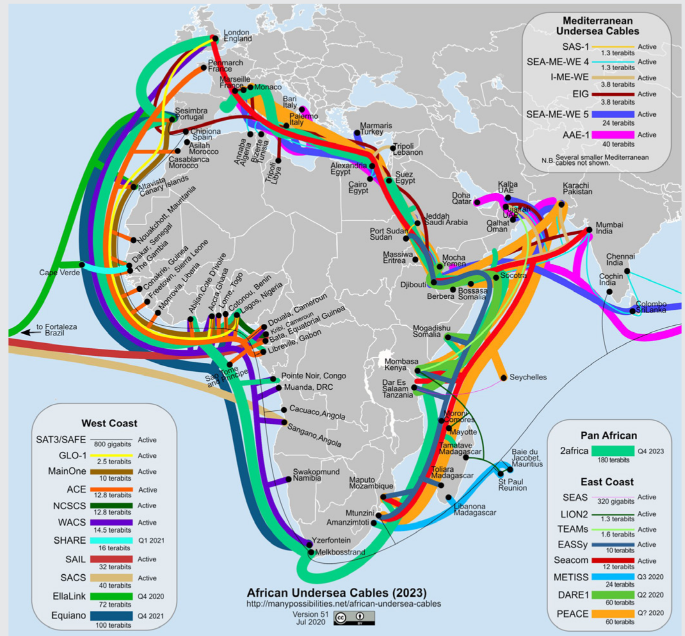
8 Feenstra, R. C., Inklaar, R., Timmer, M. 2015. The Next Generation of the Penn World Table. American Economic Review, 105(10), 3150-3182.
9 World Bank Group. 2019. World Bank Open Data.
10 The TEAMS cable is understood to have been upgraded to a higher capacity that what has been reported in industry publications.

3. Analysis Approach

We analyzed the economic impacts of subsea cables by pairing rigorous economic analysis approaches with interviews with experts in Kenyan internet connectivity. In so doing, not only were we able to understand what the impacts have been of past improvements in connectivity, but we also identified the implications of—and barriers and facilitators to—improvements in connectivity going forward. This section offers a high-level description of our approach.[11]

Note that because terrestrial fiber and wireless networks connect users to subsea cables' landing stations, we include them in the analysis. However, we emphasize that the impacts quantified are for the international connectivity associated with subsea cables and not domestic connectivity. Increasingly, nationally hosted internet exchanges, local content delivery networks, and data centers are bringing data resources stored abroad on shore. For emerging economies like Kenya, international data connectivity is important because many cloud services and data resources are stored abroad.

Figure 2. Subsea Cables in Africa.



Song, S. 2020. African Undersea Cables (2023). See https//www.manypossibilities.net.

3.1 ECONOMETRIC ANALYSES

We employed two complementary econometric methods: difference-in-differences and synthetic control. Of all available econometric methods and strategies, these two methods offer the most robust, reliable, and accurate way to estimate causal effects in the context of subsea cables. Each one of these methods derives from cutting-edge statistical techniques[12,13,14] and have been used to investigate research questions similar to those posed by our analysis.[15,16]

3.1.1 Difference-in-Differences (DID)

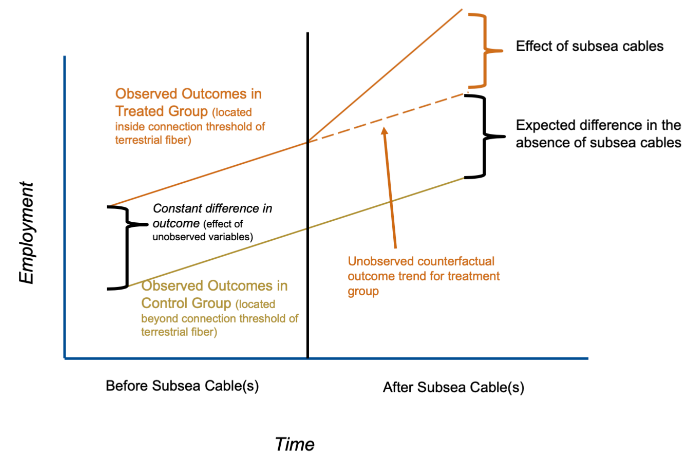
DID estimates the causal impact of subsea cables on employment and firm-level outcomes. DID consists of identifying the impacts associated with a specific intervention or treatment over some period of time. In this analysis, subsea cables (and increases in international data connectivity) are the intervention. The impact ("treatment effect") is identified by comparing the difference in outcomes before and after the intervention for the group exposed to the intervention ("the treatment group") to the same difference for the unexposed ("the control group").

In our approach, assignment to the treatment group is based on close proximity to terrestrial fiber in the base period. Being located near terrestrial fiber is a key factor that would enable individuals/firms to access the benefits of subsea cables. Because DID estimation is based on the differences in the changes that occurred between the two groups pre- and post-subsea cables, the technique inherently controls for many time-invariant factors such as age and gender. See Figure 3.

The data we used for our analysis of employment comes from the United States Agency for International Development's (USAID) Demographic and Health Surveys (DHS)[18], which ask individuals about their employment status and type of

11 A detailed technical addendum accompanies this report.
12 Athey, S., Imbens, G. W. 2017. The State of Applied Econometrics: Causality and Policy Evaluation. *Journal of Economic Perspectives*, 31(2): 3-32.
13 Baum-Snow, N, Ferreira, F. 2017. Causal Inference in Urban and Regional Economics. National Bureau of Economic Research (NBER) Working Paper Series. Working Paper 20535.
14 Imbens, G. W., & Wooldridge, J. M. 2009. Recent developments in the econometrics of program evaluation. *Journal of Economic Literature*, 47(1), 5-86.
15 Hjort, J, Poulsen, J. 2019. The Arrival of Fast Internet and Employment in Africa. *American Economic Review*, 109(3): 1032-1079.
16 Abadie, A., Diamond, A., Hainmueller, J. 2010. Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American Statistical Association*, 105.490 (2010): 493-505.
17 We use the baseline terrestrial fiber to assign treatment to avoid upward biasing the estimates. Note that the expansion of terrestrial fiber between baseline and endline only makes the estimates more conservative.
18 U.S. Agency for International Development. Demographic and Health Surveys. See https://dhsprogram.com/Data/.

Figure 3. Difference in Differences Technique for Analysis of the Impact of Subsea Cables



occupation. The data for our analysis of firm outcomes come from the World Bank's Enterprise Surveys (WBES).[19] The DHS data are geocoded, which enabled greater precision in our econometric approach than the less spatially explicit WBES data (which identify the location of firms down to the city level).

Using the DHS data, we were able to compare changes in employment outcomes (before and after subsea cables) for individuals located within a few hundred meters of the terrestrial fiber to the same changes for individuals located just beyond this distance but still located within a few kilometers of the fiber. Excluding individuals located farther than a few kilometers from terrestrial fiber and focusing on changes between groups located just on either side of a narrow margin produces a control group with high comparability to the treatment group. The resulting groups are similar in terms of both demographic and geographic characteristics, and they would arguably be subject to the same shocks (i.e. there would not be an event that affected a majority of one group but not the other) with the exception of subsea cables. Essentially, the only aspect differentiating individuals in the treatment group from members of the control group is that individuals in the treatment group may have much greater potential to access (or benefit from) high-speed internet after subsea cables arrive. Applying DID in this way enables us to tease out the effect of subsea cables from various potential confounding factors such as distance to other infrastructure and arguably any other shocks that may affect employment status, in addition to time invariant characteristics (which are inherently controlled for in DID).[20]

Because the firm-level data from WBES are spatially aggregated at the city level, we were unable to achieve the same level of specificity for firms as for individuals. For example, with a small number of cities, within which all firms are either assigned to the treatment or the control group (based on whether the city is connected to the terrestrial fiber in the baseline period), it is conceivable that an event unrelated to the arrival of subsea cables affected the outcomes of a large share of firms in one group but not the other (e.g. municipal policy changes). Therefore, we regard the impacts on firms using our DID approach as suggestive.

3.1.2 Synthetic Control (SC)

SC estimates the impact of subsea cables on economic outcomes by comparing Kenya's actual outcomes after subsea cable arrivals to a model of Kenya in which the cables did not arrive but for which all other prevailing economic trends continued. This latter version of Kenya is referred to as a synthetic counterfactual.

The synthetic counterfactual is a weighted combination of similar countries which did not receive subsea cable landings during the time period of interest and that is calibrated to Kenya's pre-arrival state. We use a weighted combination of multiple countries because the resulting counterfactual is more like Kenya across a variety of important and relevant dimensions than any single comparison country alone. Key dimensions include GDP per capita, labor composition by industry sector, and the proportion of people living in urban areas.

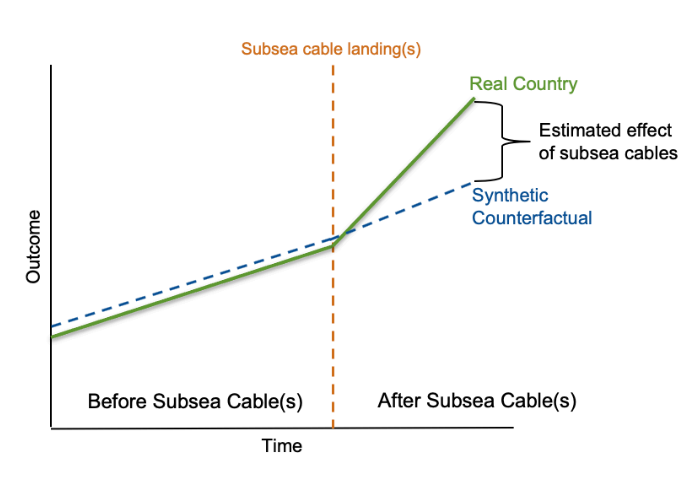
The construction of the synthetic counterfactual is completely computationally driven and optimizes the fit of the counterfactual based on the countries' actual data. Importantly, the counterfactual can be tested for its robustness and reliability, which helps assess confidence in each set of results. See Figure 4.

The country-level data we used for SC analysis come from the Penn World Table (PWT)[21] and the World Bank's World Development Indicators (WDI).[22] These sources provide

19 World Bank Group. 2019. Enterprise Surveys. See https://www.enterprisesurveys.org/.

20 Many things affect employment status, but factors that would bias the DID estimates are events that occurred between the baseline and endline surveys that differentially affected the outcomes of the two groups. Based on the method of treatment assignment, it is highly unlikely that an event systematically affecting employment outcomes for one group but not the other occurred between the two periods, besides the addition of subsea cables.

Figure 4. Synthetic Control Technique for Analysis of Subsea Cables



relevant national statistics from officially recognized sources, which are then standardized using well-documented methodology. Importantly, the detailed methodology and data quality control measures used to standardize the data enable comparison across countries and over time, and thus for our application of SC to match on a variety of important macroeconomic characteristics and outcomes.

The estimated effects using DID and SC provide complementary insights due to their similarities and differences across different dimensions, as described in Table 4. By applying two econometric methods, our work provides insight into various aspects of economic impact caused by subsea cable landings.

3.2 THEMATIC ANALYSIS OF INTERVIEWS WITH KEY STAKEHOLDERS

We interviewed 10 Kenyan broadband connectivity experts with telecommunications firms, research entities, and government agencies. Interview topics included current connectivity trends and challenges (e.g., network expansion, latency, affordability), public-sector priorities driving network expansion, role of subsea cables in the broader landscape of connectivity and internet quality, role of connectivity in economic development, and future trends and issues. So that interviewees could be open and candid, we advised that participation could be confidential, that we would not attribute responses to individuals, and that only the synthesized remarks of all interviewees would be presented in our reports.

Table 4. Similarities and Differences of Econometric Analysis Strategies

IMPACT DIMENSION		DIFFERENCE IN DIFFERENCES	SYNTHETIC CONTROL
Treatment	Subsea cables (explicitly)	●	●
Temporality	Discrete point-in-time impacts	●	●
Outcome	Employment	●	●
	Economic growth	●	●
Space	Spatially-specific impacts (specific to fiber-connected areas)	●	
	Spatially-inspecific impacts (at the country-level)		●
Data aggregation	Microdata geocoded to identify individuals/firms in fiber-connected/unconnected areas within countries	●	
	Macrodata on countries (national statistics)		●

21 Feenstra, R. C., Inklaar, R., Timmer, M. 2015. The Next Generation of the Penn World Table. *American Economic Review,* 105(10), 3150-3182.
22 World Bank Group. 2019 World Development Indicators. See https://databank.worldbank.org/source/world-development-indicators.

4. Economic Impacts of Subsea Cable Landings

4.1 IMPACTS TO DATE

Subsea cables have caused significant increases in high-skill jobs in areas connected to the terrestrial fiber, especially in places like Nairobi, Mombasa, and Kisumu. Firms and individuals in these areas have leveraged the boosts in connectivity into economic opportunity and impact.

The likelihood of being employed in a skilled occupation increased by 8.4% in areas within the average fiber connectivity radius. The increase in high-skilled employment in these areas was accompanied by a 5.9% decrease in the likelihood of being employed in a low-skill occupation,[23] as seen in Figure 5.

These results imply that for each 1 million people living in an area that is or becomes fiber-connected, 25,000 additional people tend to become employed in skilled occupations. In addition, 59,000 are employed in skilled occupations instead of lower-skilled ones. This does not necessarily mean that on balance there is a loss of jobs. Rather, it is a transformation of them because improved connectivity affects how we work.

Taken together, the evidence indicates that subsea cables caused a modest increase in overall employment in connected areas and an overall increase in job quality, driven by (1) the creation of new skilled jobs and (2) the substitution of some low-skilled jobs with jobs requiring relatively more skill. The cables helped lead to a transformation in the types of jobs available to Kenyans.

In cities connected to the fiber infrastructure we found evidence of persistent, positive effects on firms' likelihood of offering training to their employees and using information technology to conduct business. These findings are consistent with other research (e.g., Hjort and Poulsen, 2019) that describes increases in skilled jobs, activity, and growth in several industry sectors such as finance and services. We found somewhat weaker evidence of impacts on firms' productivity (i.e., revenue per worker). However, the effects likely vary among different types of firms. [24]

Figure 5. Impact of Subsea Cables on Skilled and Unskilled Employment Among Working Age Individuals in Areas Near Terrestrial Fiber

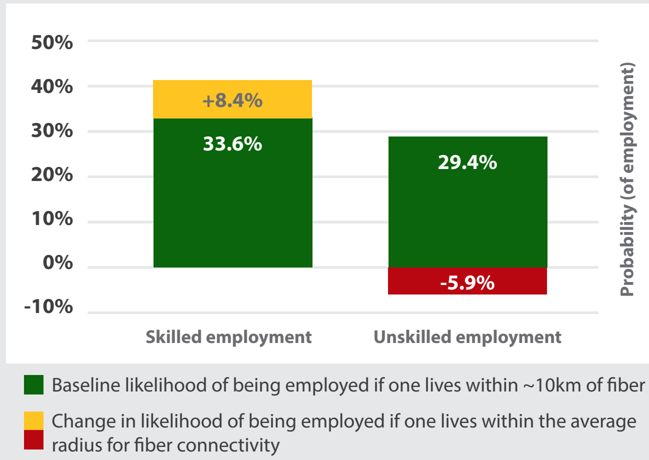
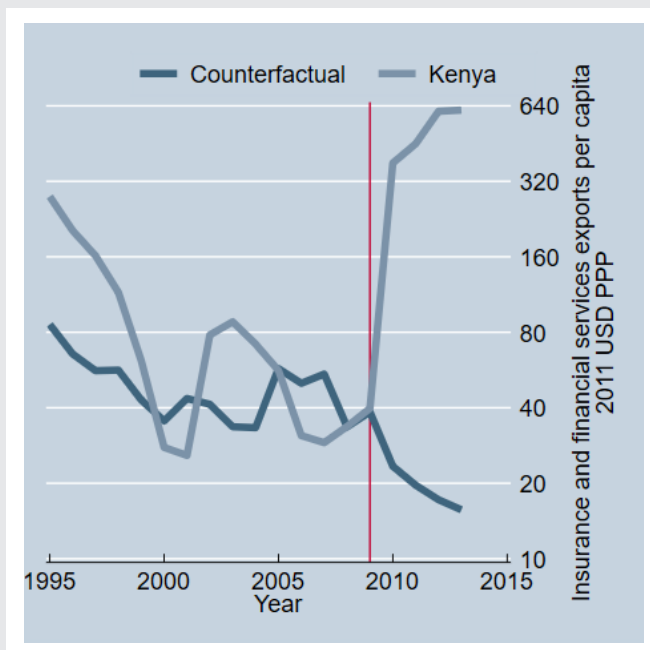


Figure 6. Estimated Effect of Subsea Cables on Financial Services Exports



Source: Authors' estimates.

23 We used DHS occupational classifications to define skilled and unskilled employment according to the International Labour Organization's International Standard Classification of Occupations, which is also consistent with the definitions used by Hjort & Poulsen (2019). DHS categorizes occupational types according to the following taxonomy: professional, clerical, skilled manual labor, sales, services, formal agricultural employment, unskilled manual labor, domestic, and self-employed agricultural employment. We defined unskilled employment to include the DHS occupational categories: unskilled manual labor, domestic, and self-employed agricultural employment. The other occupational categories were included in the definition of skilled employment.

24 Unfortunately, the high degree of geographic clustering in the WBES sample prevented us from further disaggregating our analysis to examine how effects on firm-level outcomes varied by industry or other characteristics of the business.

At the national level we found evidence of increases in financial services exports caused by the arrival subsea cables from 2009 to 2012 (e.g., TEAMS). Figure 6 shows the divergence of Kenya from the estimated counterfactual (what would have happened had subsea cables not arrived).

In 2013, four years after the first of these arrivals, Kenya's actual per capita financial services exports were approximately $600 greater (3,800% greater), than the synthetic counterfactual. In other words, without these subsea cables, we estimate that Kenya's financial services exports in 2013 would have been $16 per capita rather than the actual exports of $616 per capita.[25] This effect may seem surprisingly large, but the magnitudes are reasonable considering Kenya's substantial financial sector trade growth since 2009.

Other studies have found that financial services is among those industries most positively impacted by subsea cables due to its intense use of ICT.[26] Financial services, more so than almost any industry, is inherently dependent upon trade in order to grow, and thus greater volumes of trade in the industry are associated with a healthy financial sector. Increases in international financial trade indicate increases in the liquidity of capital and external confidence in the country's financial institutions. The size and health of the financial sector is in turn critical to aggregate economic growth because, importantly, it enables the finance of new business in other sectors of the economy.

In summary, the results indicate that the economic growth catalyzed by subsea cables is most concentrated in urban areas. There have been increases in the number of jobs available, and these jobs are higher skilled than the ones available in the past. Although the economic transformation is not yet visible in national employment of GDP per capita data, we believe it is because the impacts are not yet detectable at that level because of the overall characteristics and structure of Kenya's economy.

4.2 FORWARD-LOOKING IMPLICATIONS OF ECONOMETRIC ANALYSES

The positive effects identified on different types of employment in fiber-connected areas offer the best estimate of the likely impacts for areas that will be connected to fiber in the future. To estimate potential skilled job creation, we must assume that the causal effects already estimated for fiber-connected areas hold, on average, for areas that are still unconnected.

Figure 7 depicts the estimated actual and potential skilled job creation for all of Kenya, calculated by applying the effect on skilled employment (i.e., the increase in the likelihood of skilled employment) to population density (people per square kilometer). For connected areas, the map shows the actual estimated job creation. For unconnected areas, the map shows potential job creation if these areas were connected (assuming the average causal effect holds). The key implication is that connecting the most densely populated areas that are currently unconnected could translate to the greatest increases in skilled employment and improvements in job quality.

Numerous factors influence whether estimated effects will hold in areas that are connected in the future, including improvements to the subsea cable technology, education levels of people living in newly connected areas, and the composition of those local economies. The farther into the

Table 5. Impact of Subsea Cables on Financial Services Exports

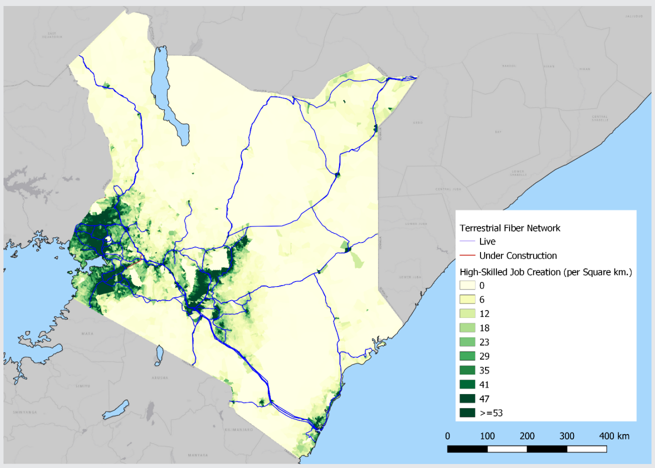
		2009	2013
2011 USD PPP	Actual	40	616
	Counterfactual	—	16
	Difference	—	600
2011 KES	Actual	1,321	20,452
	Counterfactual	—	520
	Difference	—	19,932

Source: Authors' estimates.

25 All monetary values are in 2011 USD PPP.

future one forecasts, the greater uncertainty there is around the magnitude of the impacts, owing to the potential for a large degree of change from current conditions. Nonetheless, even if the effect of connecting new areas turned out to be smaller than for the connected areas included in this study, the potential gains in terms of job quality would be socially and economically meaningful, even if net employment is unaffected.

Figure 7. Actual and Potential Job Creation as a Result of Subsea Cables and Expanded Terrestrial Fiber



Source: Authors' estimates.

5. Stakeholder Perspectives on Connectivity

Interviews with Kenyan telecommunications experts confirmed our statistical analysis results: experts described how subsea cables changed the arc of Kenya's socioeconomic development. Increased bandwidth availability has touched all aspects of the Kenyan experience, unleashing innovation and affecting how Kenyans experience daily life. TEAMS in particular brought about substantial economic change. Despite successes in network expansion across the country, an affordability challenge remains, particularly for devices. Table 6 presents key ICT indicators for reference.

5.1 MARKET STRUCTURE, COMPETITION, AND NETWORK EXPANSION

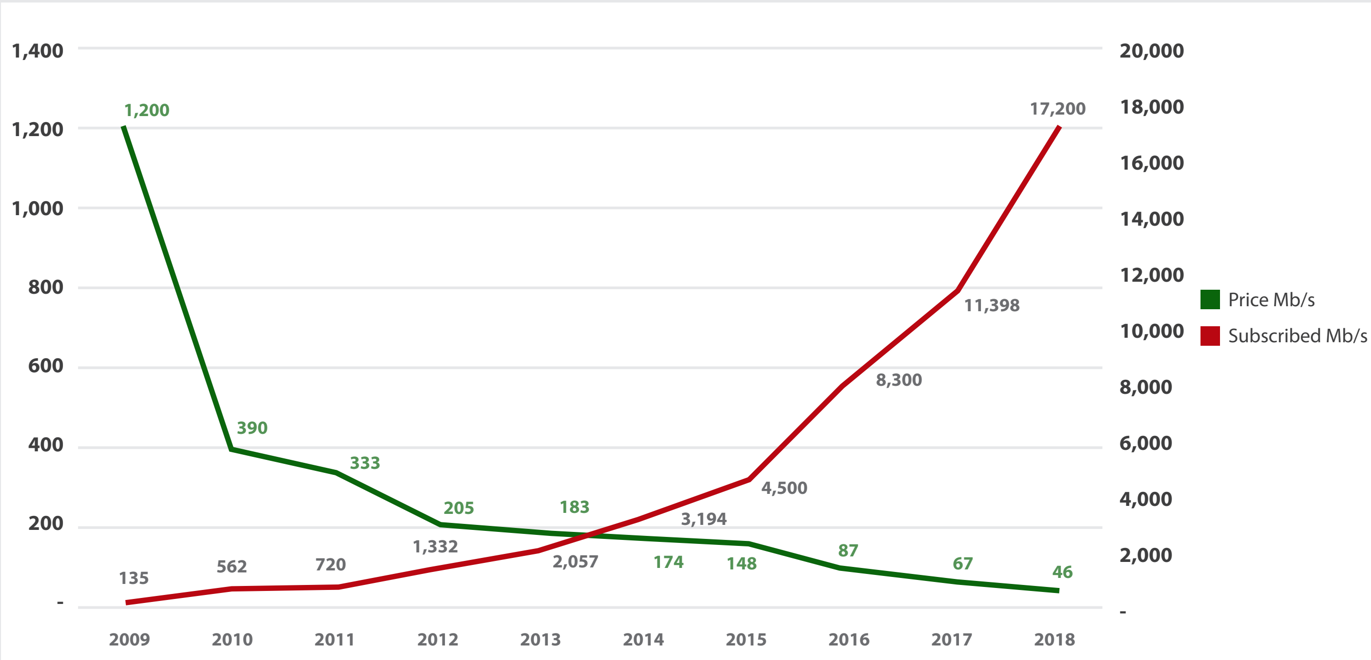
Historically, the most significant cable landing was TEAMS, a public-private partnership in which several telcos and the national government are invested. The government then funded the construction of fiber optic backbone in underserved areas to complement that of private providers. Because the most significant cable and terrestrial fiber backbone are shared infrastructure, the focus for market competitors is on subscribers, metropolitan and local fiber connections, service quality, and availability in different counties. This means that network is generally available across the country.

Table 6. Key ICT Indicators

INDICATOR	VALUE	YEAR
Electrification	64% of population with access to electricity	2017[a]
Internet users	18% of population	2017[a]
Fixed broadband subscribers	0.72 subscriptions per 100 inhabitants	2018[a]
Fixed Broadband Speed	30 megabits per second	2017[a]
Fixed Broadband Monthly Subscription Charge	28.47 (2011 USD PPP)	2017[a]
Mobile Cellular Subscribers	96 subscriptions per 100 inhabitants	2018[a]
Mobile Download Speed	20 megabits per second	2019[b]
Mobile Broadband Prepaid Subscription Charge	1.51 (2011 USD PPP per 500 megabits)	2017[a]

Sources: [a] International Telecommunication Union [b] Ookla Speedtest

Figure 8. Impact of Subsea Cables and NOFBI on Pricing and Bandwidth Available to KENET



Source: National Research and Education Network of Kenya (KENET), May 2018. See http://www.kenet.or.ke/.

5.1.1 Network Expansion Costs

Before 2009, Kenya had no subsea cable landings and relied on satellites for international connectivity. Service was expensive and had high latency. The high costs were passed on to the end consumer, contributing to low penetration of both voice and data service. TEAMS, EASSy, and SEACOM landed in quick succession which was positive for redundancy, competition, and pricing. Figure 8 illustrates trends in bandwidth and pricing for Kenya's higher education ISP, KENET.

The effort to bring fiber connectivity to Kenya was characterized by experts as a long struggle. Telcos in Subsaharan Africa had been working towards landing subsea cables in the region via an international consortium initiated in the 1990s, the East Africa Submarine Cable System (EASSy). Telkom Kenya and Kenya Data Network Ltd (KDN), which is now part of Liquid Telecom, were the Kenyan partners in EASSy.

Deciding that the EASSy collaboration was moving too slowly, the Kenyan government conceived its own project, The East African Marine System (TEAMS). TEAMS is a point-to-point link to the United Arab Emirates in partnership with Etisalat. Etisalat owns 15% and TEAMS (Kenya) Ltd 85%. TEAMS (Kenya) Ltd. is in turn owned by the government and several telcos.[27] SEACOM moved quickly and was the first to land on the Kenyan coast, followed by TEAMS, and later EASSy. A decade later, Orange built LION2 which connects to Madagascar. According to the Communications Authority (CA), about 1.5 Tbps of TEAMS's 5.2 Tbps capacity is lit.[28]

Market entry is liberalized and open to other players wishing to land cables. One planned cable is the Pakistan & East Africa Connecting Europe (PEACE). Facebook is leading a partnership that will land 2Africa in Mombasa. Interviewees suggested that the regulatory authority, CA is beginning to encourage operators to explore landing sites outside of Mombasa to enhance redundancy.

Because Mombasa is site of all subsea cable landings and a critical for fiber optic networks, an internet ecosystem has emerged there, including data centers, an internet exchange, and content distribution networks.

27 Private-sector partners in TEAMS (Kenya) Ltd include Safaricom, Telkom Kenya, Liquid Telecom, Jamii Telecom, Wanachi Group, Access Kenya Group, and BCS Group.
28 Communication Authority (Kenya). 2019. https://ca.go.ke/document/sector-statistics-report-q1-2019-2020/. Data as 30th Sept 2019.

5.1.2 Expansion of the Terrestrial Fiber Network via the National Optic Fiber Backbone Infrastructure

The National Optic Fiber Backbone Infrastructure (NOFBI) is also important to Kenya's connectivity story, according to our interviewees. With the landing of subsea cables in 2009 in Mombasa, Kenya faced a major challenge of carrying bandwidth inland. Kenya Data Networks and Telkom Kenya had launched projects to build fiber from Mombasa to Nairobi and other major cities. The government established NOFBI to link what were then eight provincial capitals as a Phase 1. The effort helped deliver capacity to rural areas.

In 2010, under a new constitution, devolution shifted political power to 47 counties. NOFBI Phase 2 was conceived to deliver connectivity to all county capitals as well as health centers and police offices. Phase 2 was therefore extensive and essentially covered the entire country. While the government constructed and owned NOFBI, it mandated Telkom Kenya to manage and operate the network and to release extra capacity to other licensed firms. Today, there are areas where NOFBI's infrastructure overlaps that of private-sector operators, but NOFBI operates as a national wholesale provider.

5.1.3 Growth in Mobile Broadband Service

Interviewees view the combination of TEAMS and NOFBI as significant in facilitating the distribution of wireless broadband connectivity across the country. In 2019, CA noted that 93% of the population was covered by a 3G signal; 59% were covered by a 4G signal (see Table 7).[29] Safaricom has announced that 5G network connectivity will be launched in 2020 after successful test trials in 2019.[30]

Most individuals access the internet via wireless data plans. There are 53.2 million wireless subscriptions, which is a 112 % penetration rate (as of September 30, 2019). CA reckons that the high penetration rate reflects multiple SIM cards among customers.[31] Nearly all (97%) mobile cellular subscriptions are on prepaid contracts, and half include broadband. [32]

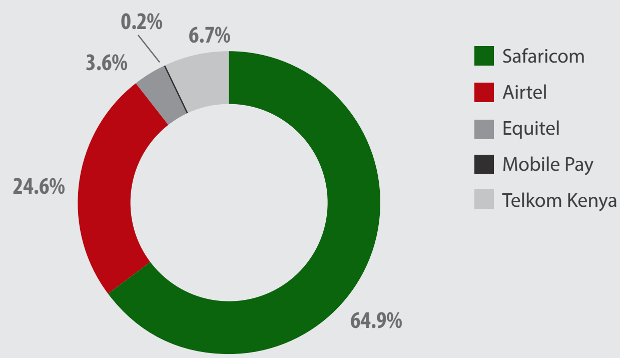
Table 7. Population Coverage by Technology, 2019

MOBILE	% POPULATION COVERAGE
2G	96
3G	93
4G	59

Source: Communications Authority.

An emergent challenge in the mobile sector is growing market concentration. The leading operator, Safaricom, has a 65% market share, and reports large profits while the other two operators are struggling and report losses. There are concerns that smaller operators could fail (see Figure 9).

Figure 9. Market Share for Mobile Cellular Subscriptions, 2019



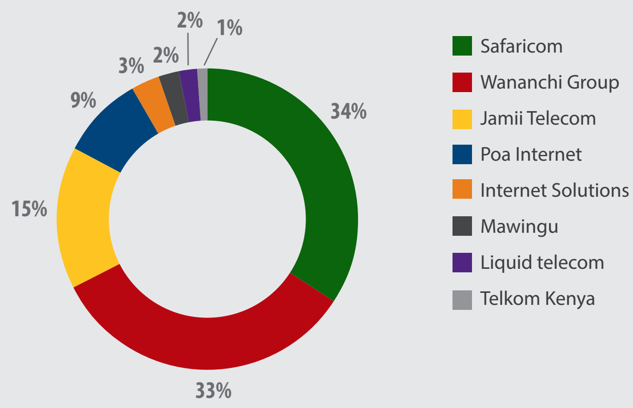
5.1.4 Wired Broadband Services

Cables influence improvements in speed, reductions in latency, and cost per MB for wired services, as they do for wireless, but Kenyans rely heavily on wireless services. There are only about 7 fixed broadband subscriptions per 1,000 people.[33] Between June-September 2019, the number of all fixed broadband subscriptions with speeds below 2 Mbps decreased, while the number of subscriptions with speeds greater than or equal 2 Mbps increased by 10.8%.[21] Internet Solutions, Jamii Telecom, Mawingu Networks, Poa Internet, Safaricom, and Wananchi are Kenya's top fixed data service providers by share of subscribers. Liquid Telecom and Telkom Kenya also support small percentages of this market.

Fiber has a higher penetration in urban areas than in others, but until recently the service was generally viewed as less

29 Areas without a signal are the focus of the government through Universal Service Fund (USF) as an intervention to empower operators to provide basic service. Going forward, CA will be focusing on providing data connectivity on 3G and above to all areas of the country.
30 Ngugi, Brian.2020. 'Safaricom to launch 5G network this year. Business Daily Africa.
31 2019 Kenya Population and Housing Census
32 GSMA. 2019.Market Overview: Kenya. London: GSM Association.
33 International Telecommunication Union.

Figure 10. Fixed Data Subscriptions by Service Provider, 2019



reliable even in those areas in which it is available. Consumers' desire, especially for those in upmarket areas, to use applications requiring higher bandwidth have invigorated the market for fiber service. By Sept 2019, the number of fixed fiber connections had grown to 450,000 connections. The leading company is Safaricom followed by Wananchi Telecom with a combined market share of 67%. Due to the cost of deployment, these connections are in upmarket areas of urban centers. A nagging headache for fiber operators is the recurrence of fiber cuts because of road construction and civil works projects. Power outages are not infrequent.

5.2 UPTAKE PROPOSITION: AFFORDABILITY, QUALITY OF SERVICE, AND CONTENT

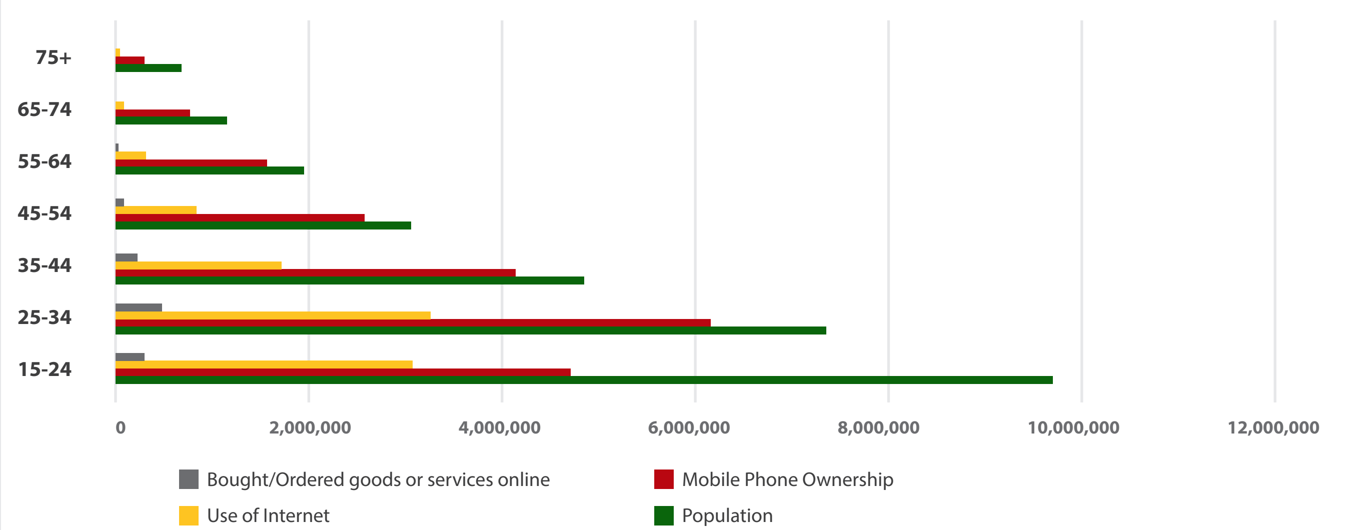
Network operators and CA are concerned about the gulf between network availability and bandwidth consumption. TEAMS and NOFBI had a direct impact on cost and stability of services, and some indirect influence on device affordability, but not enough to drive wider adoption.

Table 8. Mobile Broadband Prepaid Subscription Charge for 500 MB in Kenya and Neighboring Countries, 2017

COUNTRY	MOBILE SUBSCRIPTION CHARGE FOR 500 MB (2011 USD PPP)
Kenya	1.51
Malawi	1.62
Tanzania	1.47
Uganda	3.66

Interviewees noted that Kenya has some of lowest cost data in East Africa (see Table 8), but despite this there are signs that only about 25% of Kenyans are taking advantage of broadband internet availability. See Figure 11.

Figure 11. Mobile Phone Ownership Compared to Internet Use, 2019

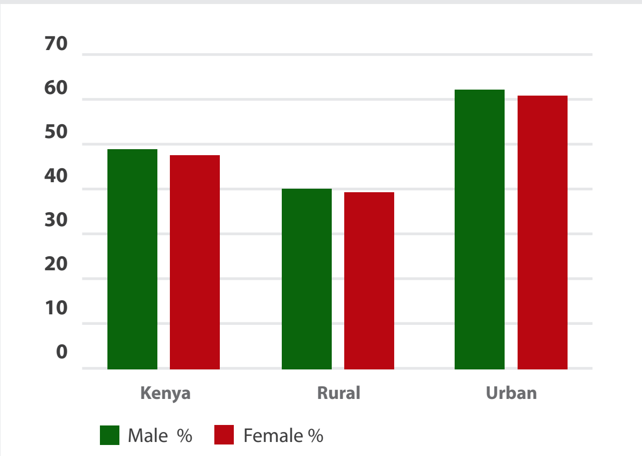


Source: 2019 Kenya Population and Housing Census.

Experts have long considered the cost of smartphones to be the principal culprit for low internet usage. Recent surveys indicate that half of Kenyans cite device costs as the most significant barrier to access.[34] Although many applications are available to those using the simplest mobile devices, limited access to robust devices limits people's ability to access more feature-rich content, government services, and e-commerce. CA is implementing projects to promote the use of data in schools and to raise awareness through telecenters in rural neighborhoods. Rates of phone ownership are lower in rural areas (Figure 12).

But, given that the critical issue in access is cost of devices and less network availability or service affordability, CA endeavors to identify perceptions of and actual barriers to gaining access to and/or acquiring devices. Subsea cables may have a direct impacts on broadband services, but its effects on device costs are much less.

Figure 12. Differences in Urban/Rural Phone Ownership, 2019



Source: 2019 Kenya Population and Housing Census.

5.3 PUBLIC POLICY PRIORITIES

In offering their perspectives on deriving the most economic development value out of subsea cables (beyond network expansion and affordability), Kenyan experts identified key areas of public policy priorities that could increase the impact of connectivity.

5.3.1 Civil Works Construction and Way Leaves for Fiber Deployment

Given Kenya's growth, especially in urban areas, there is a significant amount of civil works construction (e.g., roads and utilities) and commercial and residential development. In the absence of a "dig once" policy or consistent construction coordination it often happens that roadways or roadsides in urban areas are opened up multiple times by operators as each installs its own fiber.

In addition, new works projects often uproot or cut fiber that had been laid. This means there are frequent repairs and disruptions in service that consume capital and resources that would otherwise be available for network expansion.

There are differences in county policies, processes, and fees for fiber deployments, and some countries charge fees that are above what is common for utilities. Navigating the differences in securing way leaves adds complexity to network expansion.

The national government is keen to address these challenges and has started to implement frameworks to remedy it. As a start, the government has required road construction and other larger civil works to coordinate and provide for ducts, while housing estates must also provide for fiber infrastructure.

5.3.2 Taxation & Affordability

As discussed above, interviewees see an affordability challenge for services and devices, which creates an additional barrier to access. Again, cost of devices is an area of particular concern.

Taxation affecting the sector includes a 16% value added tax, a 15% excise duty, county fees and regulatory fees at 0.4%, and a universal service fund fee equal to 0.5% of gross turnover. The national and county governments continue to target the sector as a source of tax revenue. The Finance Act 2019 empowered the Kenya Revenue Authority to tax digital platforms for income derived from Kenya through their operations. Such operations must be registered in Kenya to do business. However, KRA is still grappling with which mechanisms to use to implement the tax. These fees are generally passed along to consumers.

5.3.3 Modernization of ICT Policies and Developing Policy Frameworks

Interviewees noted that the finalization and implementation of ICT policies can be inconsistent due to lack of specificity

34 See Communications Authority Public Consultative Paper No.1/2020: Strategies for Increasing Uptake of ICT Devices in Kenya.

and ample flexibility built into the policy design. This can result in inconsistent interpretation of policies.

For example, businesses may act on policy interpretations approved by one official but may later receive an alternate interpretation following a change in personnel. Because initial policy interpretations may not be formalized in any way, the inconsistencies can have deleterious downstream effects on business operations.

Another issue is that ICT policy modernization can be slow. It is generally accepted that the market will move faster than policy development. There is tacit support for the market to progress, so long as it does not run afoul of existing policy guidance and regulation. Until 2019, no major updates to the national ICT policy had been adopted.[35] The new policy adopts a framework and mechanism that interviewees believe should support more frequent policy updates.

Presently, the government is looking at digital economy and the 4th Industrial Revolution (4IR). Drivers are the emerging technologies of big data, artificial intelligence, internet of things, and blockchain. Indeed, the current National ICT Policy is premised on creation of an enabling environment to usher the 4IR.

5.3.4 E-Government

Interviewees emphasized that access and affordability are critical to Kenya's e-government strategy. The premise is a need for government to offer services and information efficiently to Kenyan citizens. Broadband provides a good opportunity by exploiting the fast-growing network coverage and the availability of devices at the consumer level. These devices enable the citizen access online services and for low end devices entrance to Unstructured Supplementary Service Data (USSD) to query and access services. Where citizens do not have the devices for online access or do not have the capacity to use the online services, the government has explored alternatives which includes Huduma centers[36] where citizens can be assisted to access online services.

The government built a national payment system branded e-Citizen which was launched on July 1st, 2014 and helps in user authentication, anti-money laundering, accounting and reconciliation, invoicing, and payments. E-citizen has conducted a survey on services that could be provided online and identified 5,000 of them, the government has formulated a strategy to offer them online as the premier gateway to government services.

5.4 ECONOMIC DEVELOPMENT

In May 2019, the government published the Digital Economy Blueprint[38] defining a path towards comprehensive digital transformation as a cornerstone of economic development. The government has set ambitious targets including to:

> Grow the contribution of ICT to increase the overall size of the digital and traditional economy to 10% of GDP by 2030, by using ICT as a foundation for the creation of a more robust economy, providing secure income and livelihoods to the citizenry. Leverage regional and international cooperation and engagements to ensure that Kenya is able to harness global opportunities.[39]

ICT contribution is directly and indirectly increasing efficiency across important industries and service areas in Kenya. For example, applications in productive sectors such as agriculture and social sectors such as education and skill development are increasing productivity.

As early as 2013, the government devised a program to train and promote online work under a project known as Ajira Digital.[40] It envisioned a huge online employment opportunity that would turn Kenya into a skills outsourcing destination. The government continues to provide policy and financial support on the initiative. In 2019, the government legislated incentives to youth working in the gig economy, Finance Act 2019 waives taxes on Ajira Digital youth for three years. This could help address the high unemployment rate, especially among Kenyan youth.

As the country positions itself for the next wave of technology-driven development, there will be a need for increased bandwidth to enable the use of complex systems and services, including artificial intelligence. The government is encouraging the implementation of technology into all sectors to provide innovative solutions to sector-specific challenges.

The government established a taskforce to provide a pathway for the country to tap into the emerging 4IR. The taskforce produced practical applications for AI and blockchain in daily challenges facing Kenya. Some of the projects are priority areas identified in government including food security, manufacturing, universal health care, and housing. These applications will need low latency connectivity.

Economic development policymakers expect much from broadband for country-wide development, and subsea cables

35 Ministry of Information, Communications and Technology, Kenya. 2019, November. National Information, Communications and Technology (ICT) Policy.
36 See http://www.huduma.go.ke.
37 See http://www.ecitizen.go.ke.
38 Digital Economy Blueprint: Powering Kenya's Transformation https://www.ict.go.ke/wp-content/uploads/2019/05/Kenya-Digital-Economy-2019.pdf.
39 Op cit
40 See http://www.ajira.go.ke.

6. Concluding Remarks

Our results indicate that subsea cables have played a role in Kenya's economic transformation. In connected areas, we found that subsea cable landings shifted employment from away from lower-skilled jobs (-5.9%), to higher-skilled ones (+ 8.4%), netting an increase in overall employment of 2.5%. At the national level, subsea cable landings increased financial services exports by 3,800%, a sector that relies heavily on ICT infrastructure.

As Kenya's economy continues to grow and transform, subsea cables will likely strengthen Kenya's competitive position internationally and prepare the country for fuller participation in the global economy. The types of jobs being created by subsea cables and growth of certain sectors may help to diversify Kenya's economy and create jobs that require higher level skills and pay more. This would be beneficial especially to the large share of young working age people seeking good job opportunities.

Furthermore, the analyses suggest that improvements in job quality and growth of certain sectors have likely led to increases in productivity (income) per worker in areas connected to terrestrial fiber infrastructures. This productivity increase has not yet shown up in aggregate on GDP per capita, meaning that the expansion of skilled jobs and certain industry sectors in connected areas has yet to produce sufficient net growth such that gains are detectable at the national scale. These aggregate impacts seem likely to show up eventually based on the current coverage of the terrestrial infrastructure, but increasing the share of the population and businesses in the country that have access to high-speed infrastructure may be an effective strategy to hasten those effects.

Because such dynamic economic changes affect groups within the population differently, it is advisable to consider the consequences for specific groups. While in the long-run the entire population benefits from increases in average income and higher standards of living, these changes may take time. In the meantime, it is worth considering how the changes and transitions may adversely affect the livelihoods of certain people. Similarly, despite finding no evidence of net negative effects on the overall economy, economic change and transition can adversely affect particular sectors of the economy. Thus, the evidence of creation of high-skill jobs and growth in innovative sectors, which holds the promise of resilient growth and improved living standards in the long-run, must be weighed with the trade-offs involving possible short-run losses for certain demographics and any consequences for other sectors.

Interviewees offered several recommendations. Foremost among them was the need to protect fiber infrastructure as critical infrastructure from vandalism and unintentional destruction. The latter could be achieved through a dig-once policy as well as through better civil works coordination, required marking of buried infrastructure, and information sharing among relevant organizations. A one-stop shop for rights of way and other authorizations to roll out infrastructure was a related suggestion. Several ICT analysts emphasized the importance of carrier-neutral data centers, the continuation of NOFBI construction where the economics are prohibitive for private-sector firms, and an open access policy to encourage infrastructure sharing.

Economic Impacts of Fiber Optic Subsea Cables and Broadband Connectivity in Kenya

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RTI International
3040 E. Cornwallis Road
Research Triangle Park, NC 27709