Telecommunications submarine cable deployment and the digital divide in sub-Saharan Africa

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Outline

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3. SMC deployment and the digital divide in SSA:
   - Empirical evidence from a Diff-in-Diff framework
   - SMC deployment and the spatial digital divide in landlocked African countries
   - SMC deployment and digital vulnerability
4. Concluding remarks

Motivation

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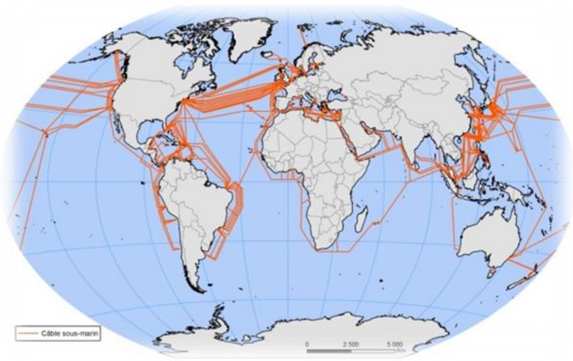
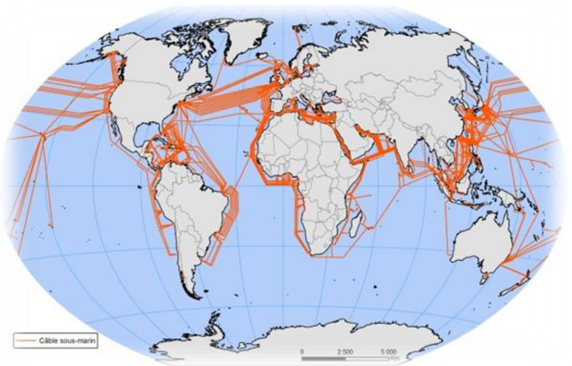
- During the last decade, international telecommunications have improved significantly with the worldwide deployment of **more than 300 fiber submarine cables (SMC)** over the period 1990-2017, channeling **99% of International telecommunications worldwide.**
- Among developing areas, Asia, South America and MENA were quickly connected through SMCs; **while SSA remained relatively isolated until 2009**.

1990

2005



2015



Today, almost all coastal African countries are directly connected to the global internet through SMCs.

Motivation

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For the last decades, international connectivity of developing countries underwent a dramatic improvement, by the laying of around **400 fiber-optic telecommunications submarine cables (SMCs):**

- Carrying 99% of international telecommunications
- Bringing fast and affordable Internet (Aker & Mbiti, 2010)
- Irrigating a USD 20.4 trillion industry, and
- Connecting 3 billion Internet users worldwide (Internet Society 2015).

In 2013, “20 households with average broadband usage generate as much traffic as the entire Internet carried in 1995” (OECD, 2013)

The submarine telecom infrastructures are now one of the **mainstays of the global economy**, but SSA has remained **digitally isolated until 2005**, with the arrival of the new generation of SMCs

Motivation

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In Africa, the growth prospects from the digital economy expansion are particularly important:

- While the internet penetration is still low in SSA compared to other developing regions, the **strong dynamism of the mobile industry is an important lever** for the development of the digital economy (ITU, 2016; Aker & Mbiti, 2010).

- **Africa should shift from 1 billion inhabitants in 2014 to 2.4 billion in 2050**, representing one quarter of the world's population, with a 15-24 year-old population rising from 200 million to more than 700 million in 2050 (30% of the population African).

It is on that continent that the **economic and social changes related to ICTs diffusion** might be the deepest.

Literature review

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ICTs are a **general purpose technology,** with a positive effect on:

- **Domestic activity:** Economic growth (Roller & Waverman, 2001; Choi & Yi, 2009; Andrianaivo & Kpodar, 2011), employment (Hjort & Poulsen, 2019) and labor productivity (Clarke et al., 2015; Paunov & Rollo, 2015; Cette et al, 2016)

- **Foreign exchanges:** trade (Freund & Weinhold, 2004; Clarke & Wallsten, 2006), attractiveness (Choi, 2003), and exports (Clarke, 2008; Hjort & Poulsen, 2019)

- **Agricultural development** (Jansen, 2007; Eygir et al. , 2011; Aker & Fafchamps, 2013)

- **Institutional quality:** Governance (Andersen et al., 2011; Asongu and Nwachukwu, 2016), political stability (Stodden et Meier, 2009)

Among other development outcomes (health, education, innovation, etc.)…

These **digital dividends in SSA economies** could be significantly improved by the **development of the telecommunications infrastructures**

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SMC deployment and the digital divide in Sub-Saharan Africa

SMC deployment and the digital divide

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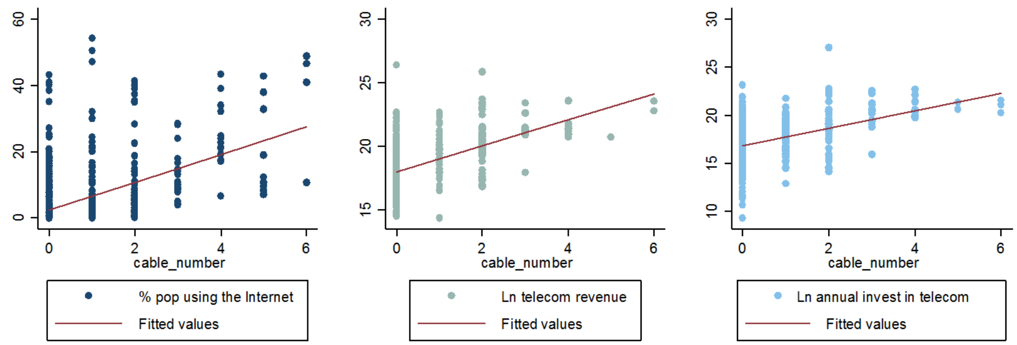
- In 2018, SSA is connected to the world Internet through 15 SMCs, 9 being spread over the West coast, and 6 over the East coast.

- The number of SMCs plugging countries to the global Internet is expected to boost the digital economy by:
  - **Widening the bandwidth**, and **fastening the internet** speed;
  - **Shortening the distance** between economic agents, and **lowering the cost of internet** access;
  - **Increasing the competition environment** between cable operators and ISPs;
  - Creating **scale economies**, and triggering terrestrial infrastructures investments;
  - **Increasing the redundancy**, and therefore **the resilience of communication networks** to cable faults and internet disruptions;

SMC deployment and the digital divide

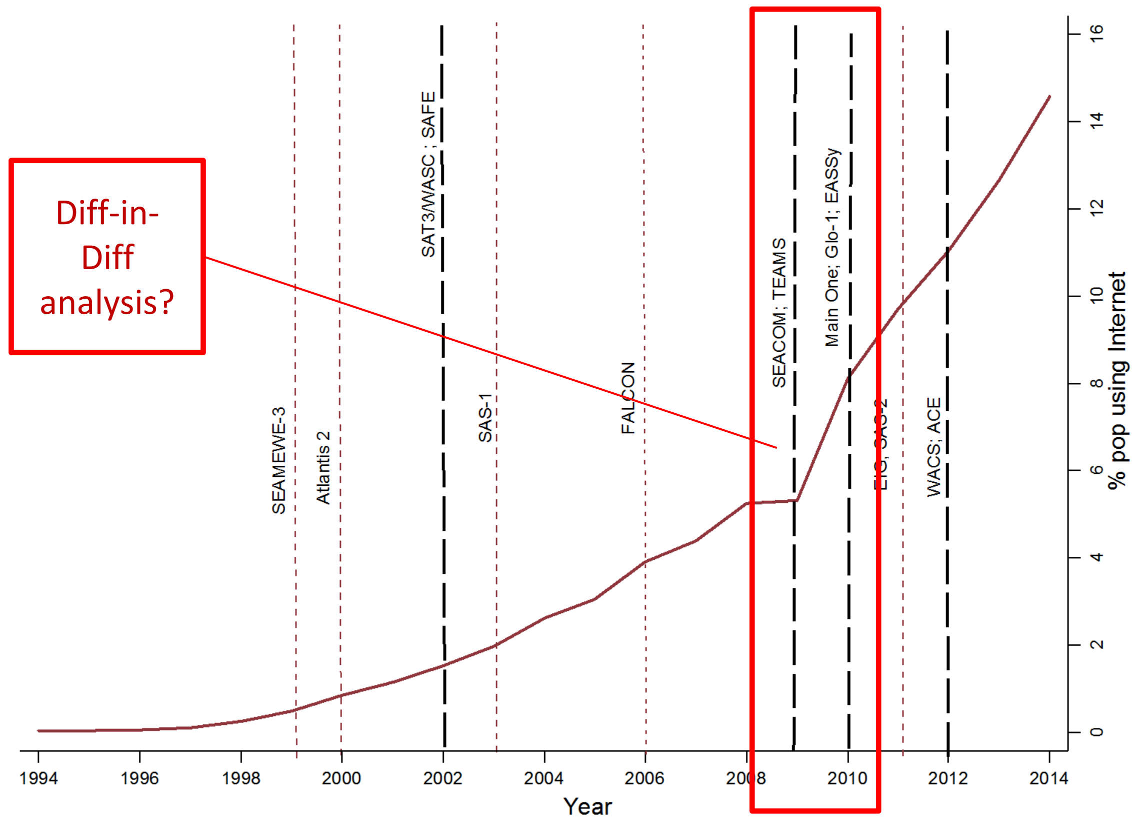
SMC deployment and the telecom outcomes,

46 SSA countries, 1990-2014.



SMC arrivals and Internet penetration in SSA.

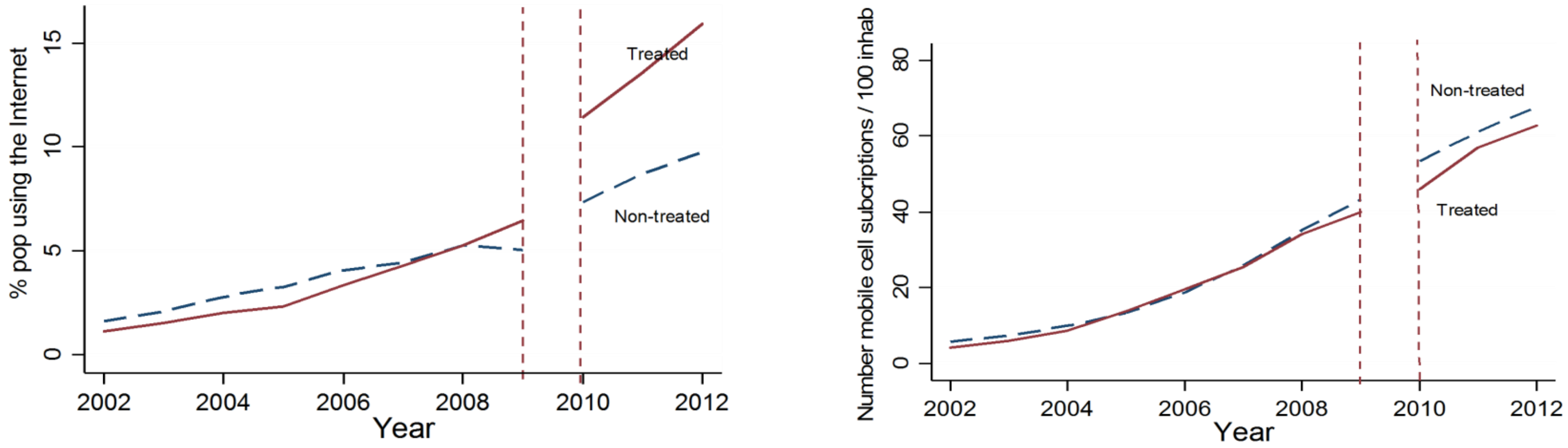
Long dashed vertical lines: arrival of a **transcontinental regional SMC**, connecting at least four African countries. Short dashed vertical lines: arrival of a transcontinental local SMC, connecting less than four African countries



SMC deployment and the digital divide

Parallel trend assumption

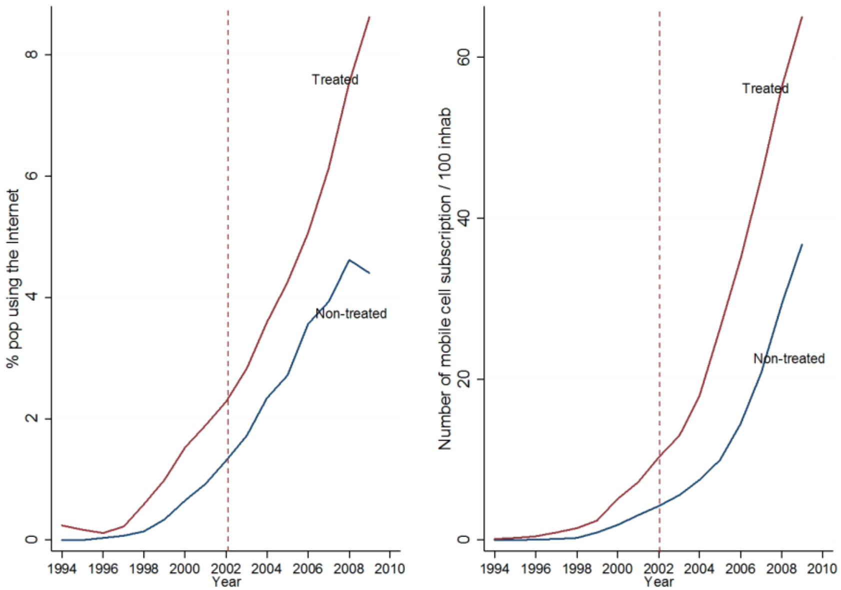
Trend comparison of telecom outcomes between treatment and control groups.



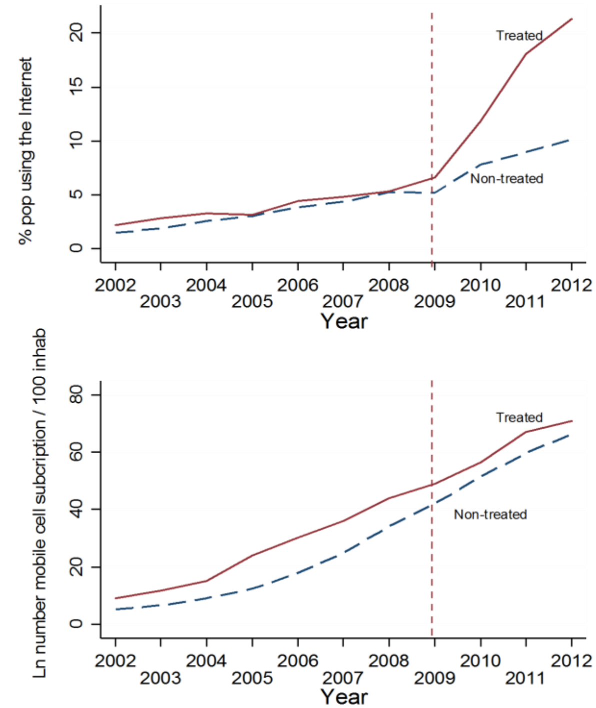
SMC deployment and the digital divide

Parallel trend assumption

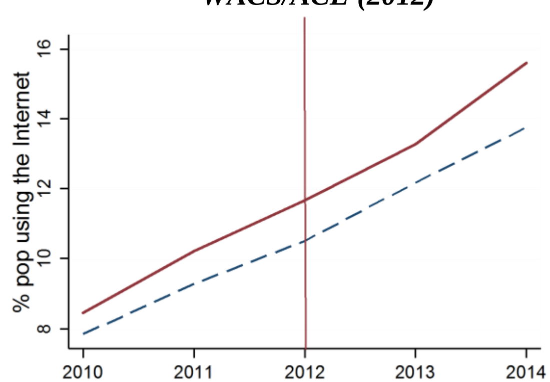
SAT3/SAFE (2002)



SEACOM (2009)



WACS/ACE (2012)



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DiD estimation framework

- The following DiD equation is estimated:

$$ICT_{i,t} = \delta_0 + \boldsymbol{\delta_1 D_{it}} + \delta_2 X_{i,t} + d_i + d_t + \varepsilon_{i,t} \qquad (1)$$

- **ICT:** % of population using Internet
- **Treatment (D_{it}):** recipients of the **2009-2010 SEACOM-EASSy-Mainone** SMCs
- **Other controls (X_{it}):** Log GDP *per capita*, the share of the population between 15 and 64-years old, the share of the urban population, the degree of democracy, the secondary education index, the share of the population having access to electricity, the number of IXPs.

Baseline sample: 46 countries over 2002-2012

SMC deployment and the digital divide

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Endogeneity concerns:

- Regional SMCs such as EASSy/Mainone/SEACOM are often deployed regionally because of the **small market-size of many SSA countries**, and because of the **high fixed-cost of this infrastructure** (Jensen, 2006).

- However, regional SMC deployment could still be influenced by national contexts

➔ Sampling restrictions:

1. **Successively excluded from the treatment group**: major economic and demographic centers (NGA, ZAF) ; SSA countries identified by Deloitte (2014) as emerging telecom markets

2. **Successively excluded from the control group:** countries located on the SMC’s path which have not been connected to it (due to bad policies probably); landlocked countries

3. **Successively excluded from both groups:** observations before 2002 (SAT3/WASC/SAFE) and after 2012 (WACS); countries recipients of local SMCs (connecting < 4 countries)

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Baseline estimations:

Dep Var.: % population using the Internet	**DID parameters (δ_1)**	**# observations**	**# treated/control obs**	**R-squared**
Sample A1: 46 SSA countries, 2002-2012.	4.136*** (4.94)	405	97/308	0.87
Sample A2: SSA excl. DJI and SDN, 2002-2012.	4.491*** (4.89)	389	81/308	0.87
Sample A3: 1990-2014	4.409*** (5.79)	798	196/602	0.76
Controls	Ln GDP/cap, % 15- to 64-yrs-old pop, % of urban pop, % pop with electricity access, 2ndary educ index, democracy, IXP number			
Time & country fixed effects	YES			

t-student in parenthesis. $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors robust to heteroscedasticity.

SMC deployment and the digital divide

Estimations with restricted samples:

Dep Var.: % population using the Internet	DID parameters (δ_1)	# observations	# treated/control obs	R-squared
		Waves 2 & 3		
Sample B: SSA excl countries being local cable host.	2.993*** (3.13)	371	63/308	0.89
Sample C: SSA excl. emerging coastal telecom markets.	3.658*** (3.83)	294	52/242	0.89
Sample D: SSA excl. unserved coastal countries	3.752*** (4.08)	344	97/247	0.87
Sample E: SSA coastal countries (excl. landlocked countries)	2.947*** (2.95)	280	97/183	0.89
Controls	Ln GDP/cap, % 15- to 64-yrs-old pop, % of urban pop, % pop with electricity access, 2ndary educ index, democracy, IXP number			
Time & country fixed effects	YES			

t-student in parenthesis. $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors robust to heteroscedasticity. **Sample B**: countries excluded from the sample **are Djibouti, Senegal, Sudan and Kenya**. **Sample C:** countries excluded from the sample are **Cap Verde, Gabon, Ghana, Ivory Coast, Kenya, Liberia, Mauritius, Mauritania, Nigeria, Senegal, South Africa, Namibia, Angola, and Eritrea**. **Sample D:** countries excluded from the sample are: **Benin, Comoros, Eritrea, Gambia, Guinea, Guinea-Bissau, Liberia, Mauritania, Madagascar, Sierra Leone, Somalia, and Togo.**

- the laying of SEACOM, MainOne and EASSy cables has yielded a 3-4% point increase in internet penetration rates in SSA.
- the impact of SMC laying on coastal countries (sample E) < estimates obtained using samples including landlocked countries:

SMCs have also impacted landlocked areas

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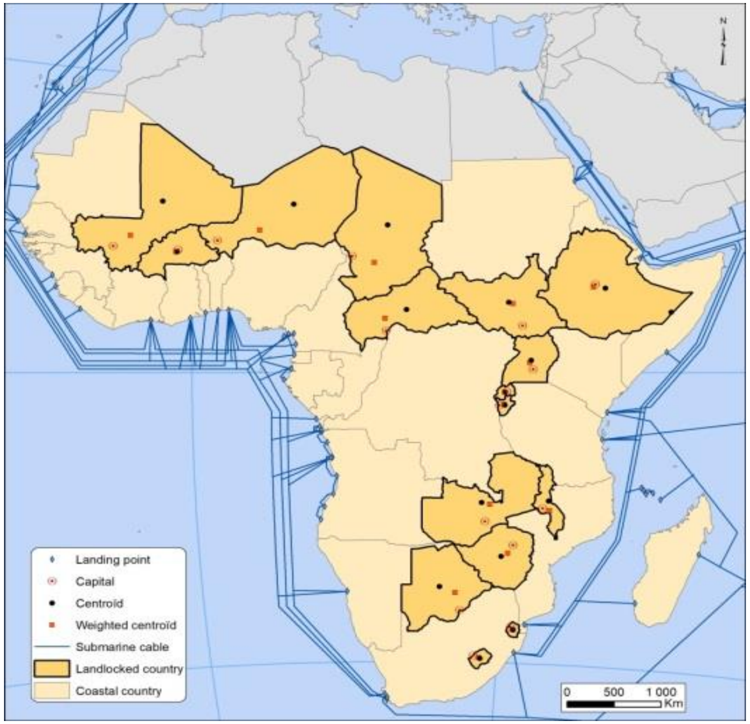
SMC deployment and the spatial digital divide in landlocked African countries

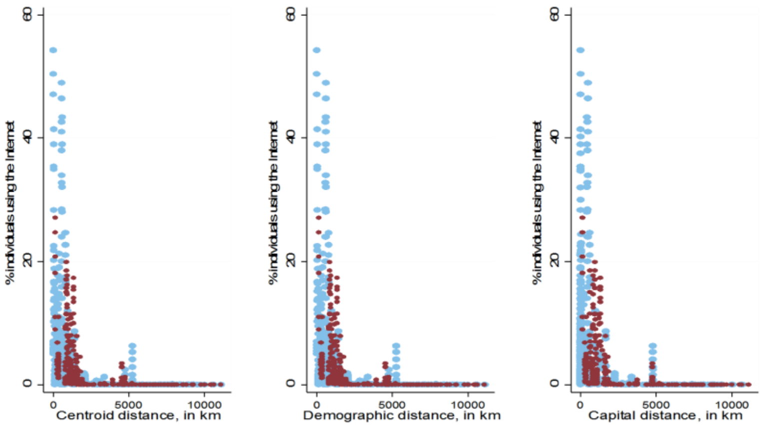
➔ Previous evidence can be explained by the **narrowing continental gap between landlocked populations and international maritime infrastructures** laid alongside the coast.

- In fact, the laying of SMCs has also reduced the **spatial digital divide** between:
  - **coastal or urban populations (the core)** close to SMC landing stations and key other backbone infrastructures, benefitting from a faster and more stable telecommunication network,
  - and **isolated inland or rural populations (the periphery)** with low infrastructure coverage and **more exposed to telecommunication network failures** (Malecki, 2002; Grubesic et al 2003; Gorman et al, 2004; Grubesic and Murray, 2006; OECD, 2013)
- The effect of the (decreasing) distance to SMC landing stations on telecommunication outcomes in landlocked countries is studied
- and indirectly addresses the possible endogeneity bias in the timing and location of SMC deployment

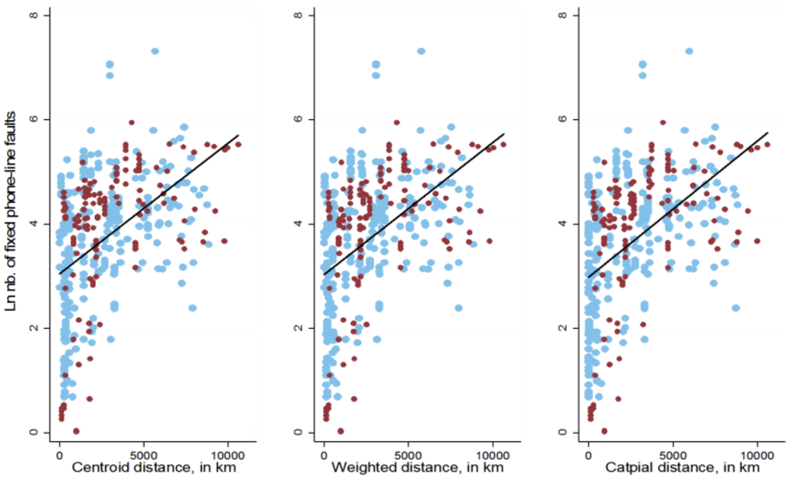
SMC deployment and the digital divide



Graphical correlations between distances to SMC landing stations and Internet penetration, SSA (landlocked in red), 1995-2015.



Graphical correlation between distances to SMC and the landline telecom network instability in SSA (landlocked in red), 1990-2014.



3 distance variables:

- **geographic centroid distance** to the closest SMC landing station
- **capital distance** to the closest SMC landing station
- **demographic centroid** distance to the closest SMC landing station

SMC deployment and the digital divide

The *within* fixed-effect estimator is applied to the following specification:

$$ICT_{i,t} = \alpha_0 + \alpha_1 . X_{i,t} + \alpha_2 . DIST_{i,t} + \theta_i + \rho_t + \omega_{i,t}$$

	(1)	(2)	(3)	(4)	(5)	(6)
	Dep var: Internet penetration rate					
Digital isolation:						
Ln geo distance	**-1.356***** **(-3.26)**	**-0.939***** **(-3.70)**				
Ln demo distance			-1.402*** (-3.33)	-0.877*** (-3.42)		
Ln capital distance					-1.384*** (-3.32)	-0.844*** (-3.38)
Controls (X_{it})	Yes					
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	Yes	No	Yes	No
Driscoll-Kraay standard errors	No	Yes	No	Yes	No	Yes
N	321	321	321	321	321	321
# countries	14	14	14	14	14	14
R^2 (within)	0.756	0.649	0.754	0.646	0.752	0.645

t-student in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are robust to heteroscedasticity, and robust to both heteroscedasticity and first-order autocorrelation in columns (3), (5), (7) and (9).

2 models:

1. Within FE model with time dummies
2. Within FE model with AR1 disturbances

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Other telecommunication outcomes:

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var	**Mobile penetration**		**Cell. prepaid charge**		**# Fixed phone-line faults**	
Ln geo distance	**-3.601** **(-1.31)**	**-1.046** **(-0.59)**	**-0.941** **(-0.84)**	**0.990** **(1.65)**	**0.492*** **(1.92)**	**0.454**** **(2.97)**
Controls (X_{it})	Yes					
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	No	Yes	No	Yes	No
Driscoll-Kraay standard errors	No	Yes	No	Yes	No	Yes
N	322	322	64	64	144	144
# countries	14	14	14	14	13	13
R^2 (within)	0.834	0.642	0.622	0.435	0.671	0.624

t-student in parenthesis. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are robust to heteroscedasticity, and robust to both heteroscedasticity and first-order autocorrelation in columns (2), (4), (6).

- Distance to SMC, in addition to reducing Internet penetration rates, **increases the telecommunication network instability**.
- This last dimension of the telecommunication infrastructure network is furthered by studying an exogenous source of telecom disruptions:

The SMC's exposure to seismic risk.

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SMC deployment and digital vulnerability in SSA

- On March 30 2018, damage to the **Africa-Coast-to-Europe (ACE) cable** disrupted telecommunications in some **10 African countries**, but more severely in 6 countries hosting only one cable (the ACE cable), which were unable to reroute and stabilize the telecommunication traffic.
- In June 2017, the anchor of a container ship cut accidentally the unique SMC linking Somalia to the world Internet, depriving the country of the Internet for more than three weeks and causing **10 million USD economic losses a day**.
- The same month, the Main-1 cable breaks 3000 km to the South of the Portugal disturbing the Internet in several countries in West Africa.

+ other experiences of faults non-reported on the web…

SMC deployment and the digital divide

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The causes and costs of SMC cuts:

- SMC cuts are caused by **human activities** (shipping, sabotage, piracy), or **natural hazards** (typhoons, floods, volcanic eruptions, seismic shocks)
- There are **direct costs for cable operators of repairing damaged cables**, amounting to millions of dollars depending on cable repair frequency and length,
- …and **indirect costs for the whole economy are related to** :
  - **The reporting of repair and insurance** costs on internet tariffs and its consequences on internet penetration;
  - **The rerouting of internet traffic** towards more expensive cable paths and its consequences on internet capacity and tariffs;
  - **The disorganization of global manufacturing** chains and internet-related service provision.

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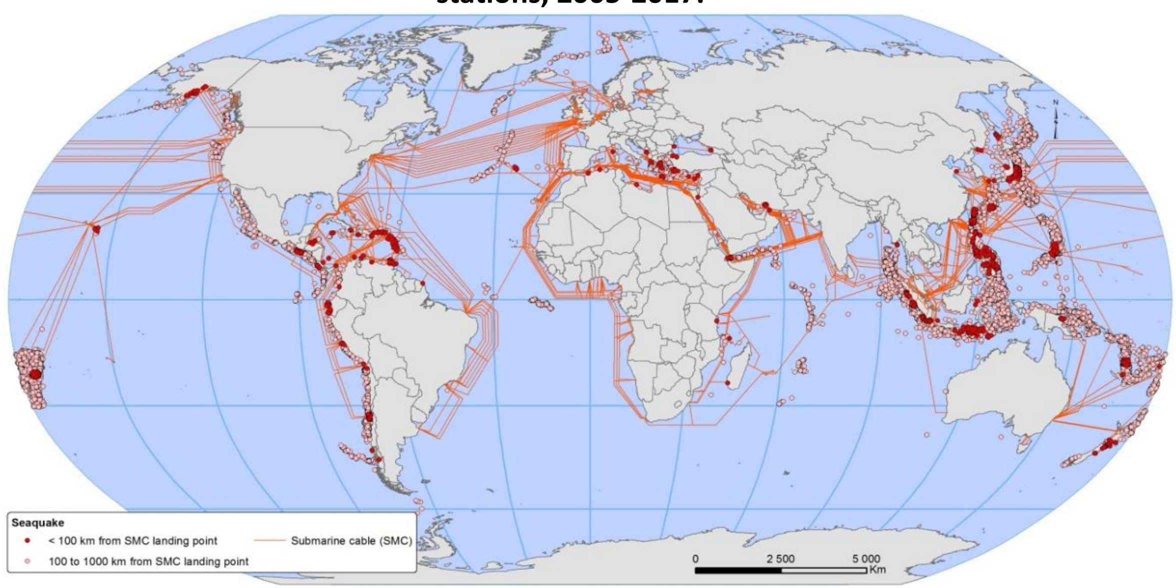
SMC exposure to seismic risk :

- Seaquakes erode or break entire sections of the cable network SMCs (multiple cables, multiple breaks)
- Destabilize the seabed into which cables are buried
- And therefore, also affect the likelihood of future faults caused by other shocks

International seismic activity within a 100 or 1000km radius from SMC landing stations, 2005-2017.



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SMC exposure to seismic risk in SSA:

Annual seaquake frequency above 5 on the Richter scale in SSA, 500km from SMC landing stations, 1995–2014

Country	Year	Seaquake freq.	Country	year	Seaquake freq.
Angola	2001	1	Kenya	2005	1
RDC	2001	1	Madagascar	2013	1
Congo, Rep	2001	1	Sudan	1996	1
Comoros	1995	2		2001	1
	2000	1		2009	1
	2002	1		2010	1
	2005	2		2013	2
	2007	3	Somalia	1997	3
	2008	3		1998	2
	2010	1		2000	3
	2012	2		2001	6
Cap-Verde	1998	1		2002	3
Djibouti	1997	2		2003	2
	1998	2		2004	2
	2000	2		2005	2
	2001	1		2006	6
	2002	1		2007	2
	2003	1		2008	3
	2004	1		2009	6
	2005	1		2010	27
	2006	1		2011	4
	2007	2		2012	2
	2008	2		2013	2
	2009	4	Seychelles	1995	1
	2010	25		2003	1
	2011	3	Tanzania	2005	3
	2012	1		2008	3
	2013	2		2010	1

Source: author. Data retrieved from Telegeography and the Northern California Earthquake Data Center.

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SMC exposure to seismic risk

The *within* fixed-effect estimator is applied to the following specification:

$$ICT_{i,t} = \alpha_0 + \alpha_1 . X_{i,t} + \alpha_2 . SMC_{i,t} + \alpha_3 . DIST_{i,t} + \alpha_4 . SMC_{i,t} + \alpha_5 . seaquakes_{i,t} + \theta_i + \rho_t + \epsilon_{i,t} \quad (3)$$

	Dep Var: Internet penetration rate				
Seaquake freq 500 km rad.	-0.123^{**}	-0.164^{***}	-0.096^{**}	-0.116^{**}	-0.0826^{*}
	(-2.52)	(-5.97)	(-2.40)	(-2.55)	(-1.91)
Lag 1 Seaquake freq. 500km			-0.257^{***}	-0.235^{***}	-0.230^{***}
			(-2.98)	(-2.97)	(-3.01)
Lag 2 Seaquake freq. 500km.				-0.212^{**}	-0.159^{*}
				(-2.42)	(-1.75)
Lag 3 Seaquake freq. 500km.					-0.384
					(-1.55)
Country dumies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	No	Yes
Driscoll-Kraay standard errors	No	No	No	Yes	No
Controls	X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$
N	920	920	920	920	920
# countries	46	46	46	46	46
R^2 (within)	0.739	0.684	0.740	0.742	0.742

Mobile penetration rate	Prepaid cellular connect. charge	# Fixed phone-line faults
-1.131^{***}	0.256	0.0823^{**}
(-4.57)	(1.02)	(2.24)
-1.244^{***}	0.0334	-0.0335
(-4.82)	(1.10)	(-0.64)
-1.427^{***}	0.0572	-0.0288
(-4.96)	(1.31)	(-0.68)
Yes	Yes	Yes
Yes	Yes	Yes
No	No	No
X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$	X_{it}, SMC_{it} $DIST_{it}$
846	218	403
46	44	
0.856	0.430	0.594

Concluding remarks

Concluding remarks

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- While the deployment of the SMC has in average reduced the digital divide in SSA,
- Its development remains hampered by the **digital isolation** of (landlocked) countries and populations remote from the International maritime infrastructure, and **exposed to the risk of SMC faults**.
- The deployment of the terrestrial infrastructure is a solution to these two obstacles, by increasing **coverage** (reducing digital isolation) and increasing the **resilience of the telecom network** (reducing digital vulnerability).

All in all, as Malecki (*Economic Geography*, 2002, p.399)'s stressed:

"interconnection is both critical to the functioning of the Internet and the source of its greatest complications".

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Thank you!