FONDATION POUR LES ÉTUDES ET RECHERCHES SUR LE DÉVELOPPEMENT INTERNATIONAL

Digital vulnerabilities and firm performances in developing and transition countries

Joël Cariolle (Ferdi), Maëlan Le Goff (Banque de France) and Olivier Santoni (Ferdi)

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- Our contribution
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- Fast internet and digital vulnerabilities
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Motivation

Over the last decades, international connectivity underwent a dramatic improvement, promoted by the laying of **321 fiber sub-marine cables** (SMC) over 1990-2015...

- irrigating a USD 20.4 trillion industry,
- connecting 3 billion Internet users worldwide (Nyirenda and Tesfaye, 2015).

- In 2013, “20 households with average broadband usage generate as much traffic as the entire Internet carried in 1995” (Weller and Woodcock, 2013)
- In 2016, more than 99% of the world telecommunications passes through SMCs.

The maritime telecom infrastructures are now the mainstay of the global economy

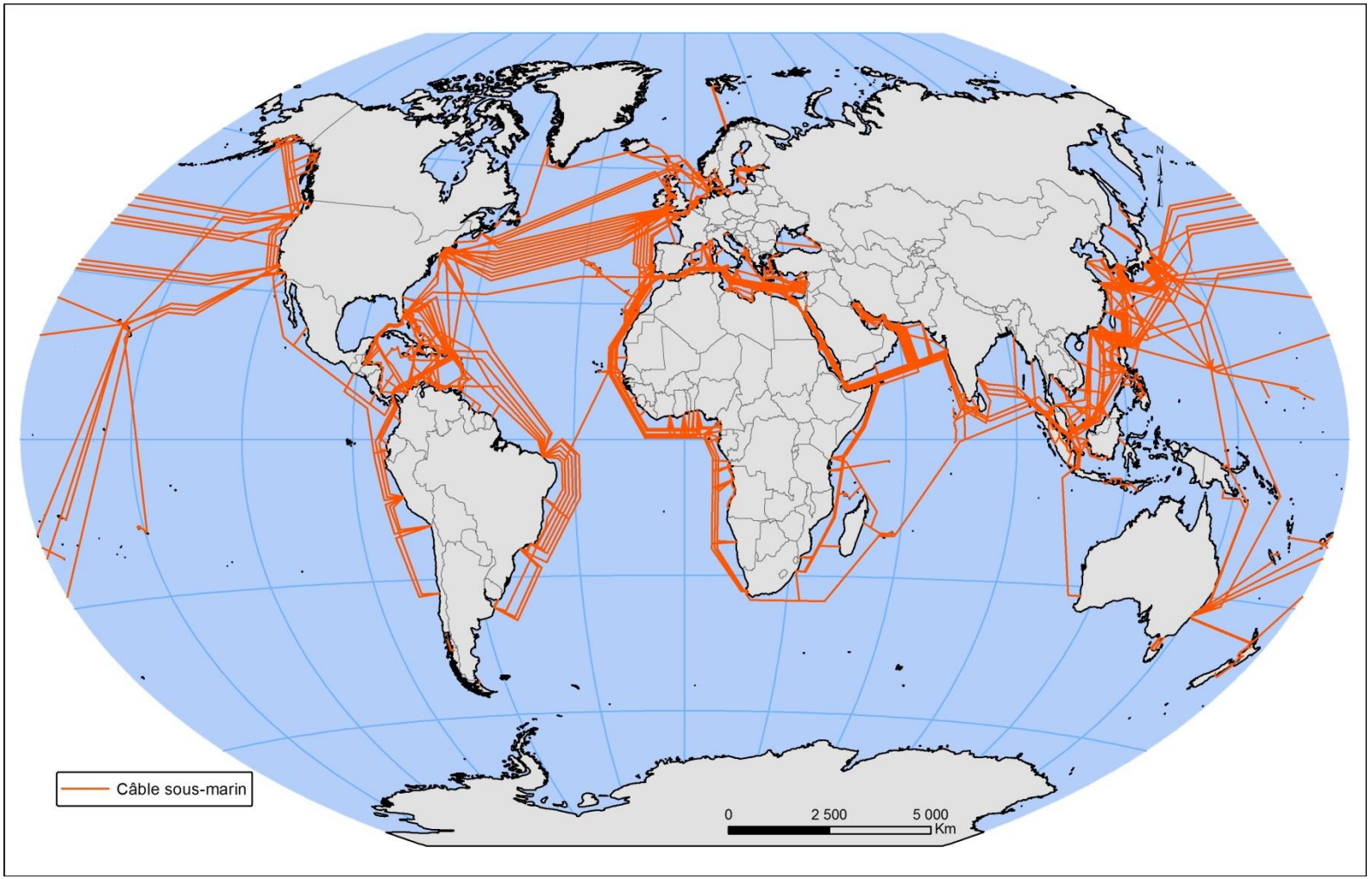
Motivation

1995

Source: www.telegeography.com

Motivation

2015



Source: www.telegeography.com

Motivation

Gordon (2012): the impact of the third industrial revolution (penetration of computers, internet and mobile phones) on the American labor productivity, is very limited compared to what happened in the wake of the first and 2nd industrial revolution.

However, a growing literature evidences a significant effect of a better access to new telecommunication technologies on economic activity in developing countries.

The digital revolution seems to be rather a developing countries' revolution.

Literature review

A positive effect of NTIC is found on:

- **Economic growth** (Choi et Yi, 2009; Andrianaivo and Kpodar, 2011), **employment** (Hjort and Poulsen, 2016) and **labor productivity** (Clarke et al., 2015; Paunov and Rollo, 2015; Menon, 2011; Cette et al, 2016)
- **Trade** (Freund and Weinhold, 2004; Clarke and Wallsten, 2006), and **exports** (Clarke, 2008; Hjort and Poulsen, 2016)
- **Attractiveness** (Choi, 2003)
- **Agricultural development** (Jansen, 2007; Eygir et al. , 2011; Subervie, 2011; Aker and Fafchamps, 2013)
- **Governance** (Andersen et al., 2011; Asongu and Nwachukwu, 2016), **political stability** (Stodden et Meier, 2009)

Our contribution

- This paper is among the first studies of the impact of broadband infrastructures on firm outcomes, with Hjort and Poulsen (2016)
- It differs from this last study by **enlarging the scope of the sample to other non-african developing and transition areas** (60-70 countries), and by controlling in our baseline model for a **wider set of broadband infrastructure variables**.
- Our contribution also lies in our **identification strategy**:

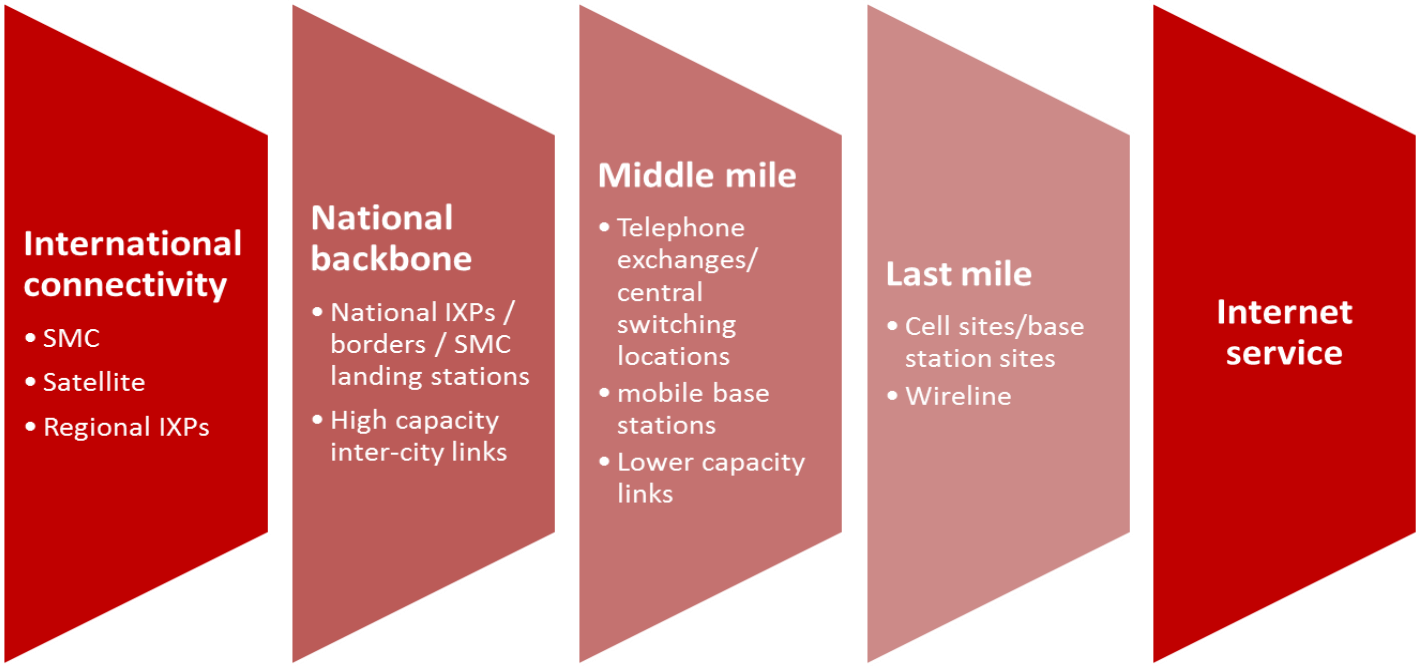
  to control for a potential endogeneity bias, we instrument firm access to Internet by exploiting heterogeneities in the degree of **digital isolation** and **exposure to telecommunication submarine cable (SMC) faults**

We find that an easier access to fast internet during firms' operations, induced by lower digital vulnerabilities, boosts their sales, their productivity, and also increases temporary full-time employment.

The internet access value chain

The Internet Access Value Chain

SMC network is the first component of the global fast Internet access value chain



Source: authors, adapted from Internet society (2015).

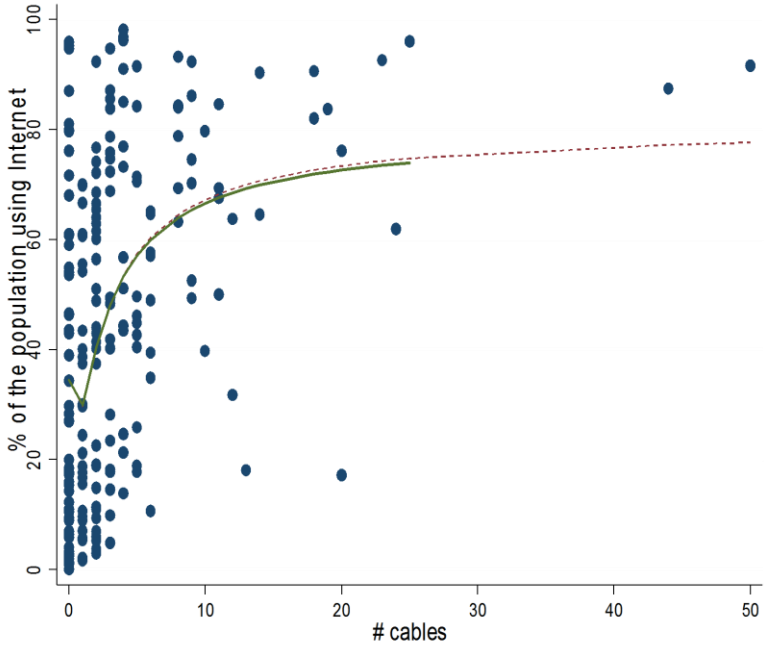
The Internet Access Value Chain

- When SMCs are missing, international connectivity is made by:
  - **Satellites** (expensive, limited bandwidth, slow)
  - **Buying bandwidth** to a SMC-connected neighboring countries (expensive, limited bandwidth)

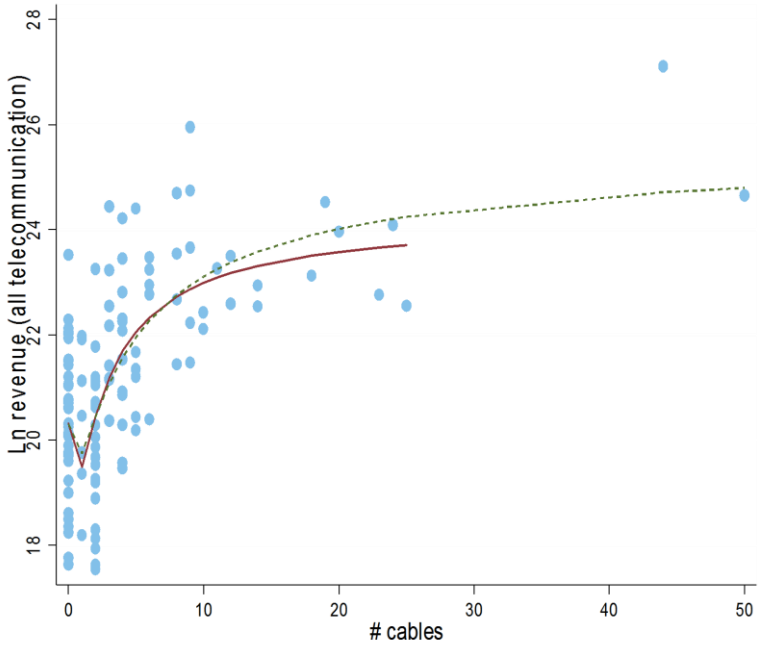
- The number of SMCs plugging countries to the global Internet is expected to boost the Internet economy by:
  - Widening the bandwidth, and fastening the internet speed;
  - Shortening the distance between internet users, and lowering the cost of internet access;
  - Increasing the competition between 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;
- But the number of SMCs is also a policy outcome: probably endogenous.

The Internet Access Value Chain

SMC deployment and the internet economy



Year: 2014. Sample: 201 developed and developing countries.



Year: 2014. Sample: 122 developed and developing countries.

Fast internet and digital vulnerabilities

Fast internet and digital vulnerabilities

- In 2016, most developing countries are plugged to the global internet, so that the remaining impediments to internet economy's growth are twofold:

  1. **The digital isolation** : the gap between internet users and the existing and often lacking terrestrial telecommunication infrastructure network;

  2. **The country's exposure to SMC faults**: induced by shipping activities (fishing nets, anchors), natural hazards, sabotage, or piracy.

We consider these two phenomena as the main sources of digital vulnerability

Fast internet and digital vulnerabilities

Digital isolation

- In countries with poor regulations and deficient telecom sector:

"fiber connectivity in cities that are far removed from submarine cable landing stations often costs five or six times as much as it does at the landing station" (Bates, 2014).

« 'The proximity of submarine cables facilitates access to low-cost mobile telephony for consumers' » (Karim Koundi, Deloitte Afrique, cited in Le Monde Afrique, 2015)

« On the other hand, in the center of the continent, the connection for the end user costs twice as much of the coast and, in fact, only four Africans out of ten own in average a mobile phone » (Le Monde Afrique, 2015)

Therefore, the distance between internet users and the existing infrastructure network is critical determinant of internet access

Fast internet and digital vulnerabilities

The exposure to SMC faults

- Between 2008 and 2012, **471 cable repairs** have been undertaken worldwide Palmer-Felgate et al (2013).

- Cable faults result from multiple factors that can be grouped into five sources of external shocks (Carter et al, 2009; Clark, 2016):
  - **Maritime activities** (fishing nets, anchors)
  - **Natural events**, such as earthquakes and seaquakes, the main source of **simultaneous multiple outages** ;
  - **Shark bits and whale entanglements**, although the new generation of cables is much less prone to these risks;
  - **Piracy and sabotages**.

Fast internet and digital vulnerabilities

The exposure to SMC faults

- There are **direct cost 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** (Widmer et al, 2010; Clark, 2016):
  - The reporting of repair 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.

Empirical strategy

Empirical model

- The core of our analysis is the effect of internet use on **firm annual sales**, **productivity**, and **temporary full-time employment**, controlling for broadband infrastructures at the national level.

- $y_i = \alpha + \boldsymbol{\beta_1 Internet_i} + \beta_2 X_i + \beta_3 V_j + \beta_4 BBI_j + \pi_s + \mu_r + \delta_t + \varepsilon_{i,j,s,r}$ (1)

- $y_i = \alpha + \boldsymbol{\beta_1 Internet_i} + \beta_2 X_i + \beta_3 V_j + \beta_4 BBI_j + \boldsymbol{\beta_5 Internet_i \times BBI_j} + \pi_s + \mu_r + \delta_t + \varepsilon_{i,j,s,r}$ (2)

y_i : variable of firm performance, $Internet_i$: firm *i*'s access to internet; X_i: firm controls; V_j: country-level controls; and BBI_j : broadband infrastructure variables. We also include sector, region and year-of-interview fixed-effects (π_s, μ_r, δ_t).

OLS ((1) et (2)) and IV-2SLS (1) **pooled estimations** are carried out on a sample of more than 25,000 firms , located in 70-60 developing and transition countries, surveyed between 2007 and 2014.

Main variables and data

Firm-level control variables (WBES)

- **Determinants of firm performance :** electricity obstacle, age, size, access to external finance, size of the city of location, % of direct and indirect exports, foreign ownership, public ownership

Macro-level controls (WDI, Polity IV)

- **Determinants of firm performance :** (ln) GDP per cap, democracy, education, landlockness, (ln) population

Infrastructure variables (authors)

- # of SMCs, # IXPs, # SMC owners by country, digital connectedness (# of directly cabled connections to other countries).

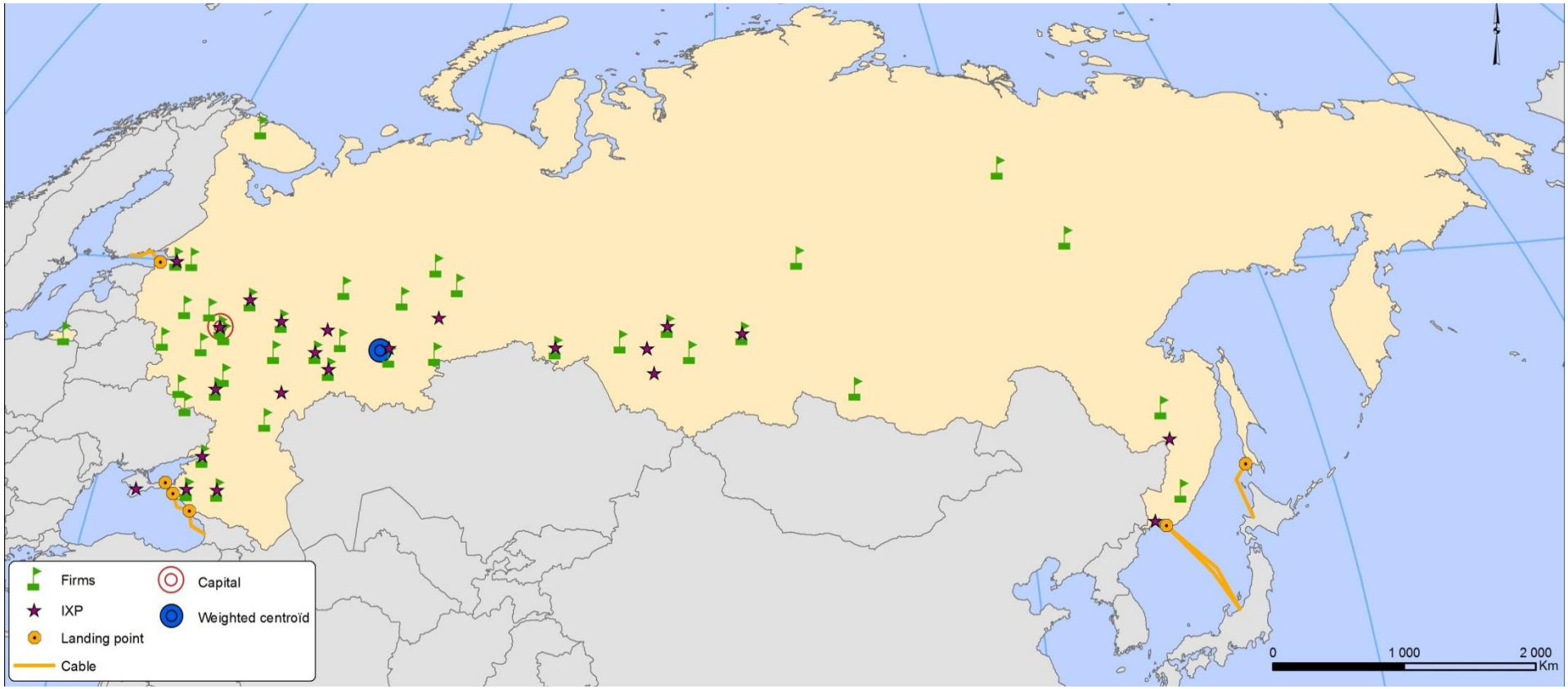
Main variables and data

Instruments of Internet use

- 3 variables reflecting countries' and firms' digital vulnerability:
  - **Digital isolation** is proxied by
    i) the **structural need for infrastructure**, that is, the weighted centroid distance from the closest SMC landing station
    ii) the **firm's need for infrastructure**, that is, the firm's distance from the closest key infrastructure nodes – SMC landing stations or Internet exchange point (IXP).
  - the **exposure to cable faults** is proxied **the annual frequency of seaquakes** which epicenters are located **within a 100km or 1000km radius from SMC landing stations** (alternatively)

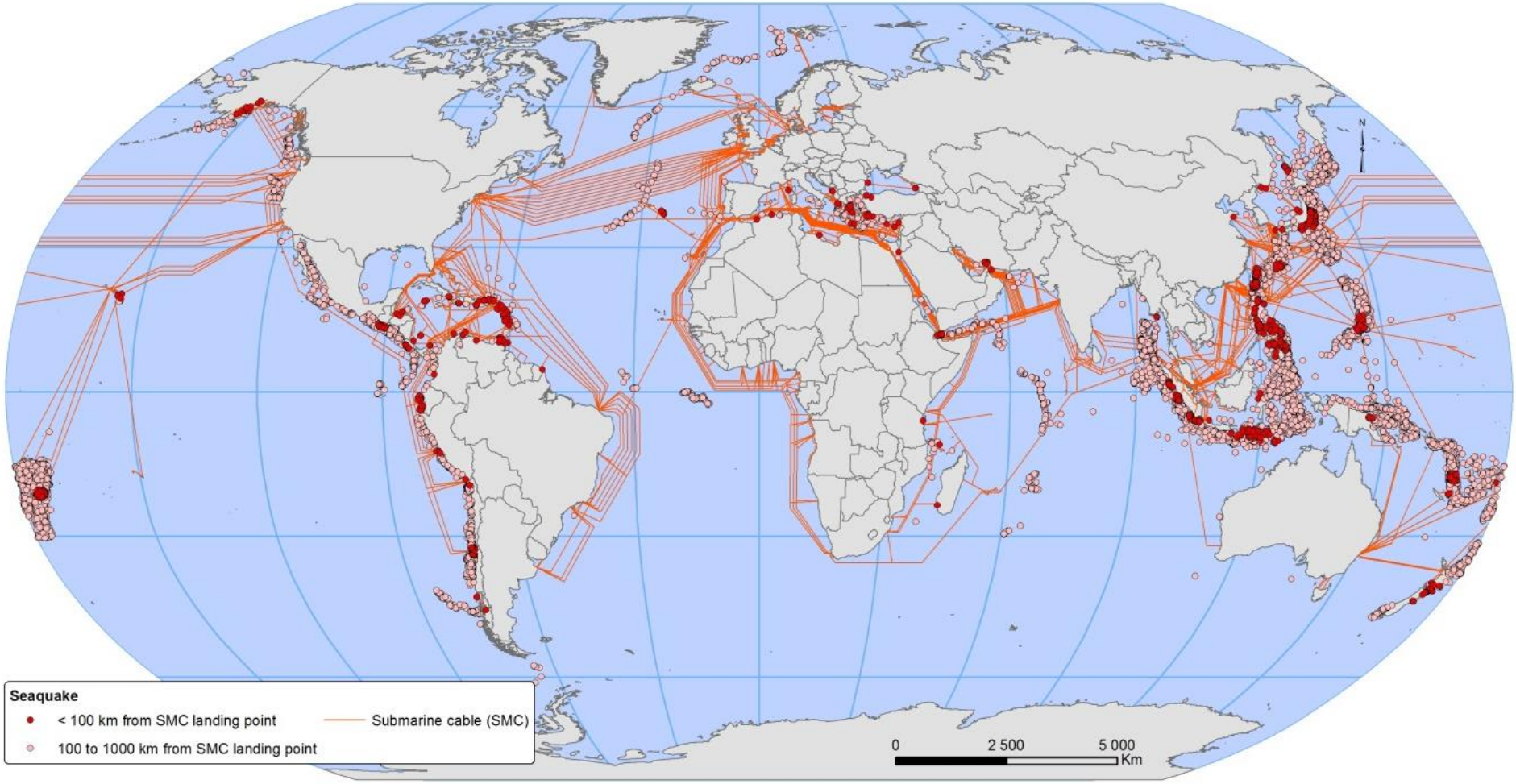
Main variables and data

Infrastructure deployment, weighted centroid and firms location in Russia



Main variables and data

International seismic activity around SMC landing stations, 1990-2016



Results

Results

Pooled OLS estimates

	TOTAL SALES				SALES PER WORKER				EMPLOYMENT			
E-mail use	**0.178*** **	**0.279*** **	**-0.166***	**0.149*** **	**0.0670*** **	**0.103*** **	**-0.118** **	**0.0522** **	**0.130***	**0.0790**	**0.0985**	**0.0692**
	(0.048)	**(0.045)**	**(0.100)**	**(0.043)**	**(0.026)**	**(0.024)**	**(0.055)**	**(0.023)**	**(0.069)**	**(0.068)**	**(0.063)**	**(0.073)**
Telecom Infrastructures												
# SMC		0.170***	0.151***	0.182***		0.0457***	0.0362***	0.0506***		-0.113***	-0.112***	-0.112***
		(0.024)	(0.023)	(0.026)		(0.013)	(0.012)	(0.0143)		(0.015)	(0.0147)	(0.015)
# IXP		0.0106	0.0135	-0.0409**		0.0199**	0.0214**	-0.000286		0.0404***	0.0403***	0.0366***
		(0.013)	(0.013)	(0.019)		(0.009)	(0.009)	(0.011)		(0.007)	(0.00708)	(0.009)
Connectedness		0.0549***	0.0570***	0.0561***		0.0374***	0.0384***	0.0378***		0.00468	0.00458	0.00475
		(0.020)	(0.020)	(0.020)		(0.014)	(0.014)	(0.014)		(0.006)	(0.00564)	(0.006)
Time 1st cable		-0.274***	-0.286***	-0.279***		-0.145***	-0.151***	-0.147***		-0.00403	-0.00351	-0.00426
		(0.037)	(0.038)	(0.037)		(0.026)	(0.027)	(0.026)		(0.006)	(0.00642)	(0.006)
# of cable		0.0239	0.0221	0.0228		0.0234*	0.0225*	0.0230*		0.00442	0.00453	0.00432
owners		(0.019)	(0.019)	(0.019)		(0.013)	(0.013)	(0.013)		(0.005)	(0.00524)	(0.005)
Mail use x # SMC			**0.0756*** **				**0.0375*** **				**-0.00335**	
			(0.018)				**(0.010)**				**(0.0106)**	
Mail use x # IXP				**0.0561*** **				**0.0220** **				**0.00422**
				(0.017)				**(0.009)**				**(0.007)**
N	34786	34567	34567	34567	34705	34488	34488	34488	39904	39626	39626	39626
Countries	70	68	68	68	70	68	68	68	74	72	72	72
R2	0.426	0.531	0.537	0.533	0.460	0.532	0.536	0.532	0.173	0.185	0.185	0.185

Note : All estimates include region, year and sector fixed effects. Standard errors are presented in parentheses: * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are robust to heteroscedasticity and are clustered by country-year-city-sector.

Results

IV 2SLS estimates

(firm-level observations)

	TOTAL SALES			SALES PER WORKER			EMPLOYMENT		
2nd stage	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
E-mail use	**14.907*** (4.895)**	**6.382** (2.690)**	**5.928** (2.728)**	**7.602*** (2.637)**	**3.579** (1.728)**	**3.379* (1.775)**	**1.375 (1.020)**	**2.087*** (0.592)**	**2.091*** (0.590)**
1st stage estimates (var: mail use)									
Ln Firm distance to SMC or IXP	-0.006* (0.003)	-0.0025 (0.005)		-0.006* (0.003)	-0.003 (0.005)		-0.006** (0.003)	-0.002 (0.004)	
Ln weighted centroid distance to SMC	-0.034** (0.016)	-0.029* (0.015)	-0.031** (0.015)	-0.035** (0.016)	-0.031** (0.015)	-0.032** (0.015)	-0.036** (0.017)	-0.041*** (0.016)	-0.036** (0.016)
Seaquakes freq., 100 km rad.	-0.001* (0.000)			-0.001* (0.000)			-0.001** (0.000)		
Seaquakes freq., 1000km rad.		-0.008*** (0.001)	-0.008*** (0.001)		-0.007*** (0.001)	-0.007* (0.002)		-0.007*** (0.001)	-0.007*** (0.001)
All controls		YES							
Hansen test (p. value)	0.189	0.140	0.199	0.133	0.238	0.156	0.120	0.197	0.072
Weak ident. test (F-stat)	11.222	18.31	9.568	11.535	18.19	26.61	16.791	24.80	36.85
Under-ident. Test (LM-stat)	11.030	25.95	7.923	11.660	25.85	25.56	13.356	27.46	27.36
Observations	33280	26374	26488	33202	26309	26422	38175	29637	29766
Countries	68	62	62	67	62	62	71	66	66

Note : All estimates include region, year and sector fixed effects. Standard errors are presented in parentheses: * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are robust to heteroscedasticity and are clustered by country-year-city-sector.

Results

IV 2SLS estimates

(city-sector averaged observations)

	(1)	(2)	(3)
2nd stage	TOTAL SALES	SALES / WORKER	EMPLOYMENT
E-mail use	**4.436****	**2.608****	**1.765*****
	(2.067)	**(1.200)**	**(0.638)**
		First stage est	
Ln Firm distance to SMC or IXP	-0.0146** (0.006)	-0.0145** (0.006)	-0.0147*** (0.006)
Ln weighted centroid distance to SMC	-0.0640*** (0.022)	-0.0638*** (0.022)	-0.0602*** (0.023)
Seaquakes frequency 1000 km	-0.0055*** (0.002)	-0.0055*** (0.002)	-0.0049** (0.002)
Macro and micro controls		YES	
Hansen test (p. value)	0.93	0.92	0.83
Weak ident. test (F-stat)	12.46	12.42	12.29
Under-ident. Test (LM-stat)	20.42	20.37	17.79
N	2610	2607	2773
Countries	62	62	66

Note : All estimates include region, year and sector fixed effects. Standard errors are presented in parentheses: * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are robust to heteroscedasticity and are clustered by country-year-city.

Results

IV 2SLS estimates : the effect of website use

(city-sector averaged observations)

2nd stage estimates	TOTAL SALES	SALES / WORKER	EMPLOYMENT
website use	**5.283****	**3.077****	**1.848****
	(2.609)	**(1.545)**	**(0.785)**
First stage estimates			
Firm distance to SMC or IXP	-0.015**	-0.015**	-0.019***
	(0.007)	(0.007)	(0.006)
Weighted centroid distance to SMC	-0.035	-0.035	-0.028
	(0.023)	(0.023)	(0.023)
Seaquakes frequency 1000 km	-0.004**	-0.004**	-0.004**
	(0.002)	(0.002)	(0.002)
Macro and micro controls	YES		
Hansen test (p. value)	0.70	0.74	0.83
Weak ident. test (F-stat)	4.81	4.80	6.71
Under-ident. Test (LM-stat)	13.48	13.49	14.29
N	2608	2605	2771
Countries	62	62	66

Note : All estimates include region, year and sector fixed effects. Standard errors are presented in parentheses: * significant at 10%, ** significant at 5%, *** significant at 1%. Standard errors are robust to heteroscedasticity and are clustered by country-year-city.

Concluding remarks

Concluding remarks

- IV estimations put in evidence the positive contribution of NICT to firms' performances in developing countries.

- An increased used of e-mail, website (and a lower telecommunication constraint) are found in a consistent way to stimulate sales, productivity, and temporary employment.

- These results point out the contribution of the fast internet infrastructure to the economy, by highlighting the concomitant digital vulnerabilities some developing countries may be subject to:
  - in fact, in some countries, the arrival of fiber boosts the internet economy
  - but may have enlarged the digital divide between coastal and inland areas, and increased the economy's exposure to fiber cable breaks and internet shutdowns

Thank you!