

Digital vulnerability and local performance of firms in developing and transition countries

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

- ❑ Bringing fast and affordable Internet to developing countries (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)

In 2016, more than 99% of the world telecommunications passes through SMCs.

The submarine telecom infrastructures are now one of the mainstays of the global economy

Motivation

Contribution

Empirical framework

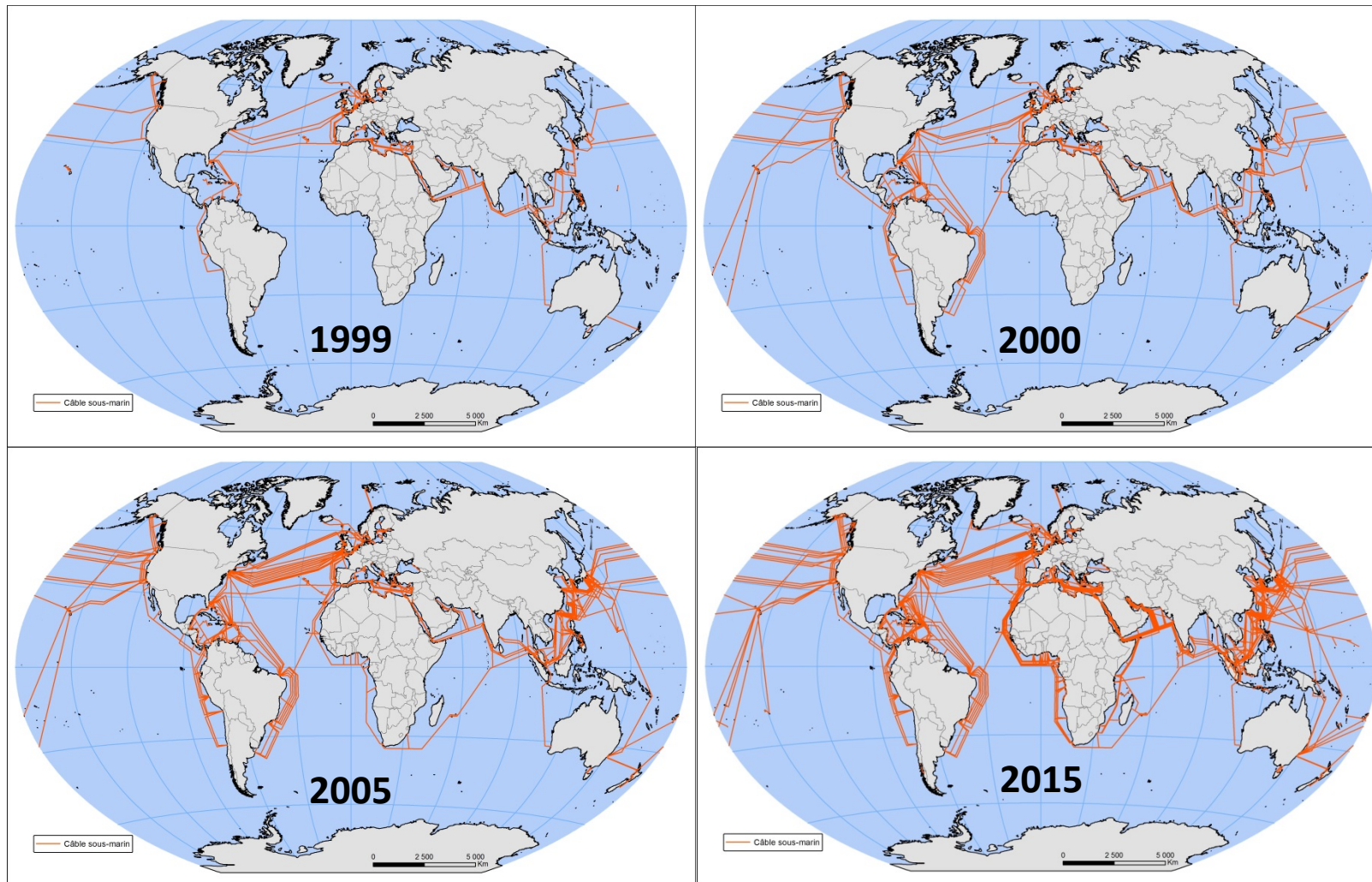
Results

Conclusion

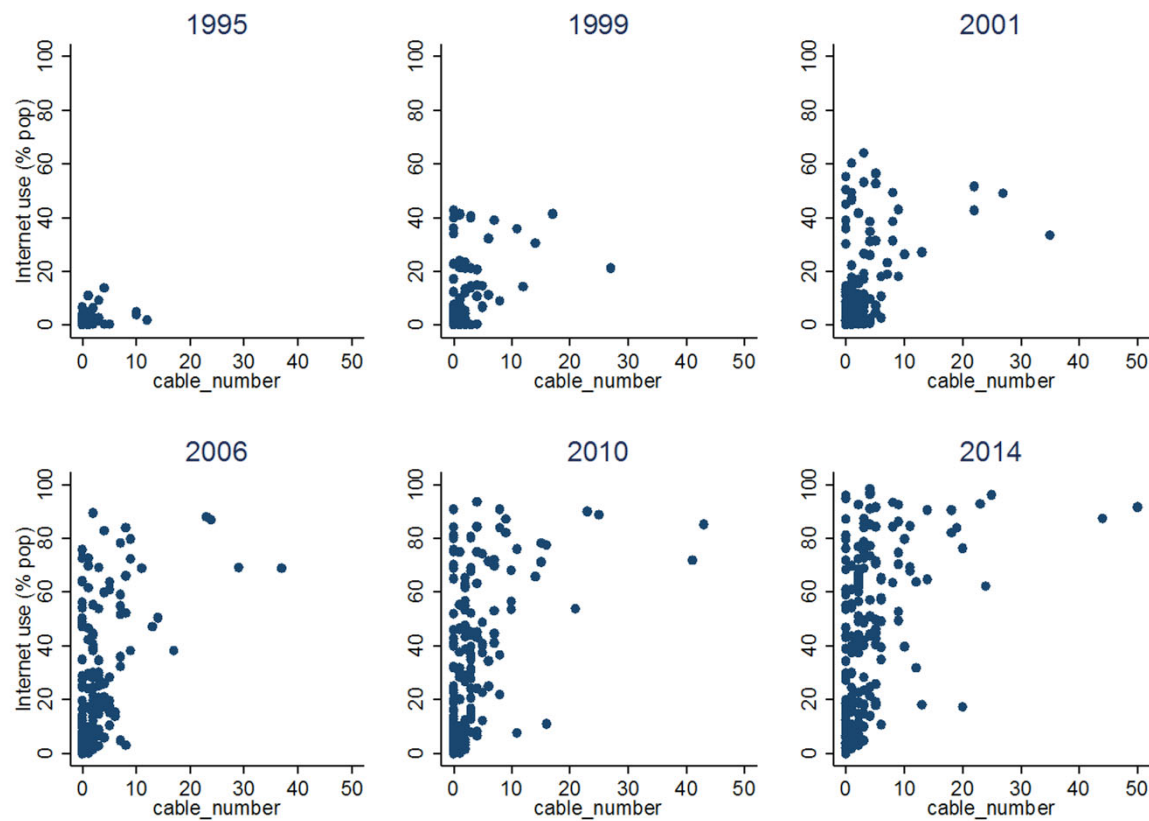
Model

Data

IV framework

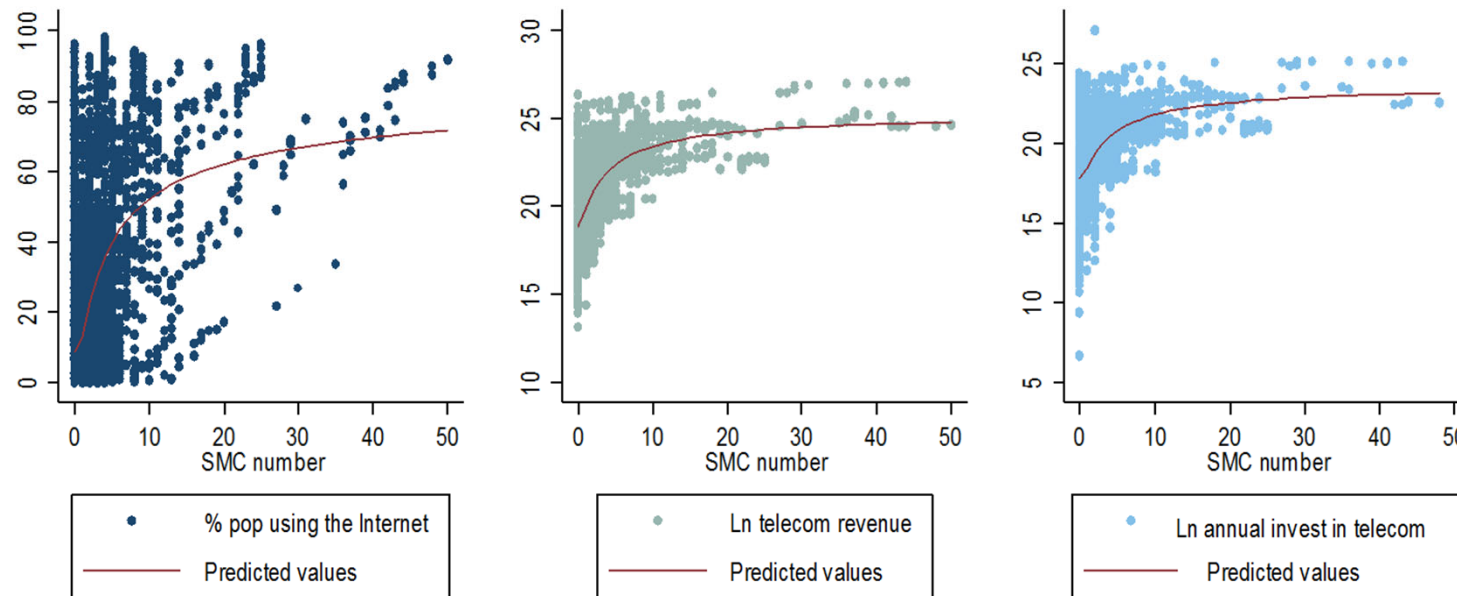


SMC deployment and Internet penetration worldwide



Notes: Raw data from ITU (2016) and Telegeography (2016).

SMC deployment and telecommunication outcomes



Notes: world evidence, 1990-2014. Raw data from ITU (2016) and Telegeography (2016).

What are the expected dividends from the deployment of these cables, *a fortiori* from ICTs diffusion in developing countries?

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; Cetté 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.)...

This paper brings additional insights into this line of research by:

- ❑ Providing evidence on the location-level impact of Internet use by firms on their **revenue, labour productivity, and employment**.
- ❑ Conducting the analysis at the location level to account for network externalities and within-country heterogeneity in Internet penetration among firms
- ❑ Adopting an instrumental variable approach, emphasizing a new vulnerability arising from SMC deployment: **the SMC network's exposure to seismic risk**.

This paper indirectly tries to provide an answer to the following question:

What happens to firms when the SMC network integrity is threatened ?

The model

Using data aggregated at the location-level, we estimate the following general model:

$$Y_{j,l,t} = \gamma_0 + \gamma_1 Internet_{j,l,t} + \gamma_2 X_{j,l,t} + \partial_j + \mu_r + \sigma_l + \delta_t + \beta_{j,t} + \varepsilon_{j,l,t} \quad (1)$$

- subscripts, l , t , j , r respectively refer to the location, the survey year, the country, and the region.
- $Y_{j,l,t}$, and $Internet_{j,l,t}$ are respectively variables of firm's performance, and firm's Internet use. $\varepsilon_{j,l,t}$ is the error term.
- $X_{j,l,t}$: average number of full time permanent employees when the firm has started operations, the firm's age, the ownership structure (state and foreign ownership, in %), the % of direct and indirect exports, the frequency of power outages, and the sector of activity.
- We also control for country (∂_j), year (δ_t), country x year ($\beta_{j,t}$), region (μ_r), and for location (σ_l) fixed effects.

The data

Sample of more than 30,000 firms, located in around 125 cities/provinces in some 38 developing and transition countries.

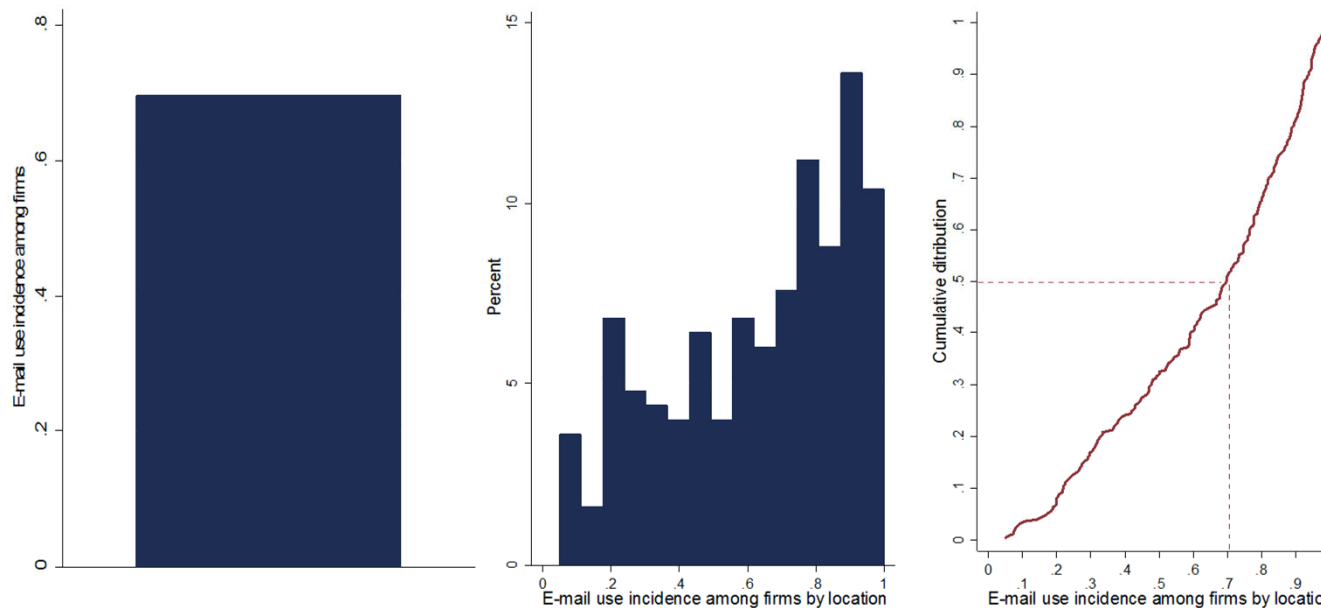
All firm-level variables used in our model are drawn from the World Bank Enterprise Survey (WBES) harmonized cross-sectional dataset.

A **pseudo panel** is built by aggregating at the location level firm-level data from the World Bank Enterprise Surveys (city or province), and keeping locations where firms have been at least twice surveyed:

- ❑ **To account for local externalities** between firms' decisions located in the same place, that could bias estimates;
- ❑ and **to control for local unobserved heterogeneity**, by applying the within FE estimator.

Interest variable ($Internet_{i,t}$)

- % of firms which declares having used emails to communicate with its clients and suppliers during the past year
- most basic way to use Internet, reflecting both simple and more complex usages of the Internet



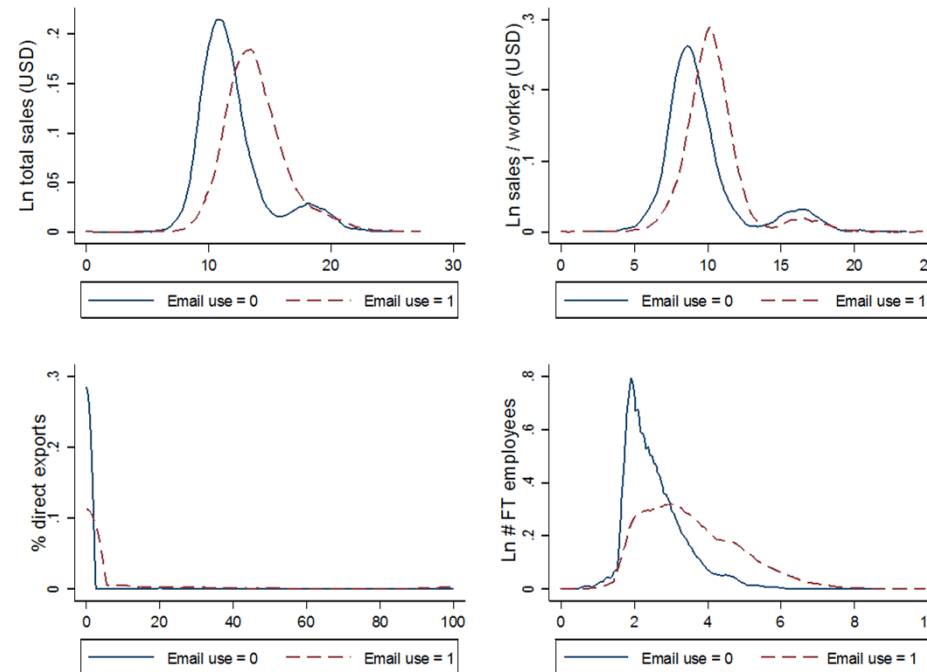
4 main outcome variables (Y_{it}):

- ☐ Log total annual sales (in USD).
- ☐ Log sales / FT permanent employees
- ☐ % of direct exports
- ☐ Log # of FT permanent employees

+ 4 employment variables in manufactures:

- ☐ Log # of production workers
- ☐ Log # of non-production workers
- ☐ Log # of skilled production workers
- ☐ Log # of unskilled production workers

Firm outcomes & Internet use.



IV framework

- FE 2-stage least square estimator (FE-2SLS), adding the 1st-stage equation to eq. (1):

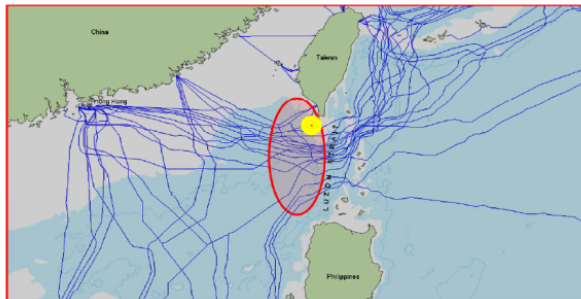
$$Internet_{l,t} = \alpha_0 + \delta_1 Instruments_{j,l,t} + \alpha_2 X_{j,l,t} + \partial_j + \pi_s + \mu_r + \sigma_l + \delta_t + \beta_{j,t} + \varepsilon_{j,l,t} \quad (2)$$

Instrument_{j,l,t} = SMC network exposure to shocks_{j,t} (A) x Location exposure to telecom disruptions_{j,l} (B)

- Our instrument combine two structural interrelated sources of digital vulnerability :
 - (A): the **SMC network exposure to seismic shocks**
 - (B): **digital isolation**, i.e. the location distance from key infrastructures, increasing the exposure to telecommunication disruptions.
- Location fixed-effects: control for location's time-invariant characteristics explaining firm's location choice and outcomes
- Region, country, year, country-year fixed effects: control, among others, for the endogenous timing of SMC laying in a given country.

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
- Affect the likelihood of future faults caused by other shocks

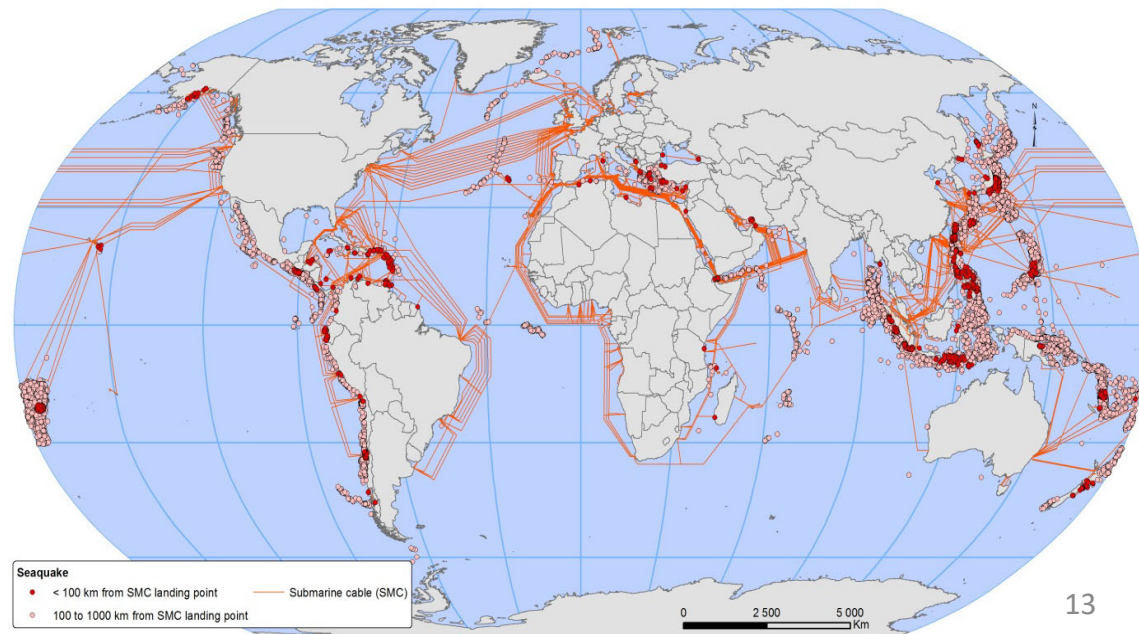


Earthquake epicentre (yellow dot) and the general area of the disruption of the submarine cables (blue lines). Courtesy Global Marine Systems Ltd

Taiwan earthquake (7 on RS) in 2006. 8 SMC cuts.

Disrupted East-Asian & international telecommunications

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



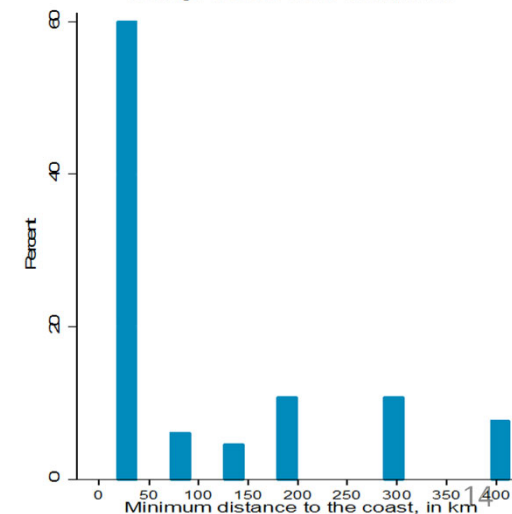
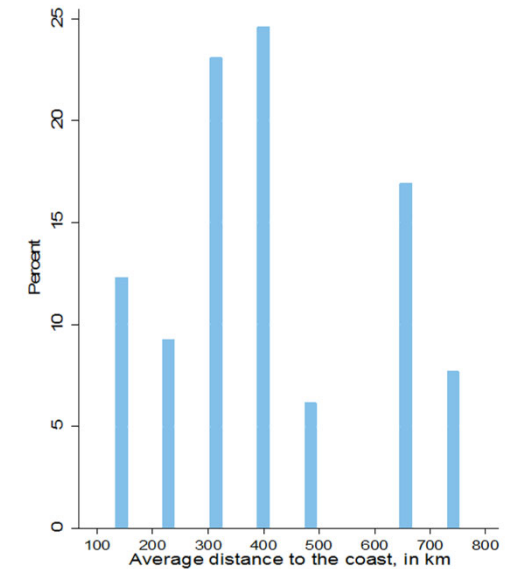
SMC exposure to seismic risk

Seismic shock variable = the **annual frequency of medium size seaquakes** that are likely to affect only the functioning of SMCs,

- ☐ i.e. located within a **100-1000km radius from SMC landing stations**
- ☐ Low-magnitude seaquakes (<5 on Richter scale) **are not counted**
- ☐ Obs. with high-magnitude seaquakes (>6.5 on Richter scale) **are dropped**

Robustness:

- ☐ Drop observations when the minimum distance of seaquakes to the coast < 50km (60% instrument obs.).



Digital isolation

When telecommunication assets are geographically concentrated (mostly the case in developing countries), locations distant from telecommunication nodes, are :

- ❑ More exposed to telecommunication disruptions (Grubescic and Murray, 2006; Grubescic et al, 2003),
- ❑ and are slower to recover after telecommunication shutdowns (Gorman and Malecki, 2000; Gorman et al., 2004).

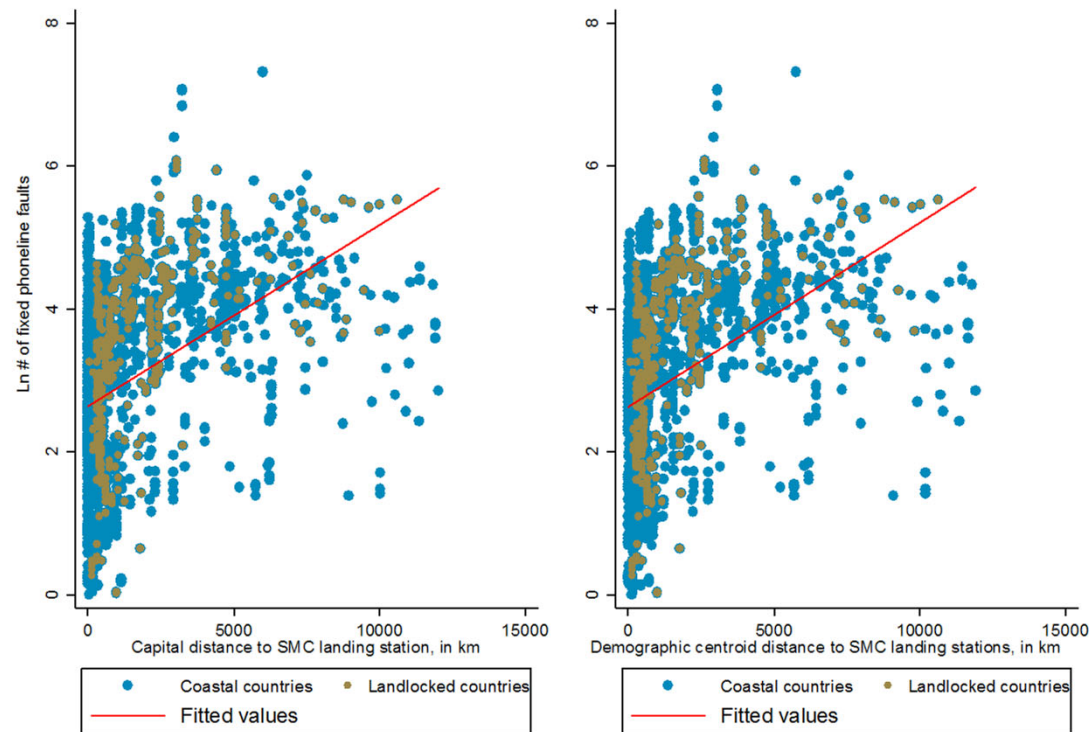
Digital isolation variable parametrisation:

- ❑ We compute the (ln) distance in km between locations' centroid and the closest key infrastructure nodes GPS coordinates.
- ❑ Infrastructures nodes are **SMC landing stations** or **Internet Exchange Points**, which are key infrastructures for the telecom network's capacity and efficiency.

Robustness:

- ❑ distance set to 0 for locations within 100km rad from infrastructure nodes
- ❑ Excluding from the sample firms located in capital cities
- ❑ Excluding from the sample firms located in provinces

Digital isolation



Source: authors. **Notes:** 169 countries, 1920 observations.

Instrument set

The instrument set combines:

- ❑ **Instrument_{i,t} 1:** Seaquake freq, 100-500km radius x Ln location distance to infrastructures
- ❑ **Instrument_{i,t} 2:** Seaquake freq, 500-1000km radius x Ln location distance to infrastructures

Take into account non linear effect depending on seaquake distance to SMC, and to compute identification stat.

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Baseline estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Var dep:	(ln) Total sales		(ln) Sales per worker		(ln) # FT employees		% direct exports ^a	
Email use	2.088** (0.849)	3.690*** (0.906)	2.176*** (0.625)	2.607*** (0.573)	0.305 (0.804)	1.156*** (0.389)	6.946 (5.069)	3.152 (4.977)
State-owned		2.236 (1.582)		2.011* (1.146)		-0.413 (0.715)		-6.784 (8.734)
Foreign		-3.192** (1.591)		-2.685** (1.048)		0.302 (0.535)		23.22** (9.983)
Age		0.374 (0.245)		-0.0951 (0.209)		0.579*** (0.197)		-6.593*** (1.798)
# power outages		-0.456*** (0.150)		-0.289*** (0.111)		-0.0184 (0.039)		0.0230 (0.903)
% of exports		0.0298*** (0.00823)		0.0153 (0.0105)		0.007* (0.003)		-0.157 (0.184)
Initial # of FT employee		0.358*** (0.138)		0.221 (0.141)		0.0155 (0.0780)		0.435 (1.530)
First stage estimates								
Seauquake freq 100-500km x Ln dist infra	-0.0022*** (0.0004)	-0.0026*** (0.0005)	-0.0022*** (0.0004)	-0.0026*** (0.0005)	-0.0021*** (0.0004)	-0.0025*** (0.0005)	-0.0022*** (0.0004)	-0.0025*** (0.0005)
Seauquake freq 500-1000km x Ln dist infra	-0.0031** (0.0016)	-0.0039*** (0.0014)	-0.0031** (0.0016)	-0.0039*** (0.0014)	-0.0027* (0.0014)	-0.0039*** (0.0014)	-0.0027* (0.0014)	-0.0039*** (0.0014)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Fixed effects	Country, year, country-year, sector, region, location							
Hansen test (p. value)	0.24	0.27	0.24	0.72	0.24	0.33	0.55	0.56
Weak-identification SW F-test	18.20***	17.81***	18.20***	17.81***	18.44***	17.81***	18.44***	14.98***
Underidentification SW Chi-sq.	48.31***	48.92***	48.31***	48.92***	48.74***	48.92***	48.74***	41.13***
N	273	251	273	251	289	251	289	251
# locations	136	125	136	125	144	125	144	125
# countries	41	38	41	38	44	38	44	38
# aggregated firms	43,539	32,178	43,539	32,178	46,408	32,178	46,408	32,178

Manufacture vs Service

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Var dep:	Sales		Sales/worker		Direct exports ^a		Ln # FT employees	
	Manuf	Services	Manuf	Services	Manuf	Services	Manuf	Services
Email use	-0.232	4.595***	0.602	1.497	13.48	-0.445	0.398	1.497***
	(1.482)	(1.157)	(0.910)	(0.935)	(8.381)	(9.168)	(0.710)	(0.482)
First stage estimates:								
Sequake freq 100-500km x Ln dist infra	-0.0025*** (0.0005)	-0.0015*** (0.0004)	-0.0025*** (0.0005)	-0.0015*** (0.0004)	-0.0025*** (0.0005)	-0.0015*** (0.0004)	-0.0015*** (0.0004)	-0.0015*** (0.0004)
Sequake freq 500-1000km x Ln dist infra	-0.0026 (0.0020)	-0.0061*** (0.0014)	-0.0026 (0.0019)	-0.0061*** (0.0014)	-0.0026 (0.0019)	-0.0061*** (0.0014)	-0.0061*** (0.0014)	-0.0061*** (0.0014)
Controls	Yes							
Fixed effects	Country, year, country-year, sector, region, location							
Hansen test (p. value)	0.51	0.25	0.34	0.23	0.71	0.24	0.26	0.24
Under-ident. SW F-test	10.33***	9.84***	10.33***	9.84***	10.33***	9.84***	10.33***	9.84***
Weak indent. SW Chi-sq	28.52***	26.73***	28.52***	26.73***	28.52***	26.73***	28.52***	26.73***
N	243	251	243	251	243	251	243	251
# locations	121	125	121	122	121	125	121	125
# Countries	38	38	38	38	38	38	38	38
# of aggregated firms	16,244	15,934	16,244	15,934	16,244	15,934	16,244	15,934

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors are presented in parentheses, are robust to heteroscedasticity and clustered by country. a: controls include the share of indirect exports, instead of the share of direct and indirect exports used in other regressions.

Outlier detection and removal (Grubbs test)

	(1)	(2)	(3)	(4)
Var dep:	Total sales	Sales / worker	Direct exports ^a	# of FT employees
Email use	3.005*** (0.855)	2.201*** (0.769)	5.093 (4.672)	1.156*** (0.388)
1st stage est.				
Seauquake freq 100-500km x Ln dist infra	-0.0025*** (0.0006)	-0.0025*** (0.0006)	-0.0024*** (0.0005)	-0.0026*** (0.0006)
Seauquake freq 500-1000km x Ln dist infra	-0.0031*** (0.0014)	-0.0032*** (0.0014)	-0.0039*** (0.0015)	-0.0039*** (0.0014)
Fixed effects	Country, year, country-year, sector, region, location.			
Controls	Yes			
Hansen test p-value	0.81	0.43	0.70	0.33
Under-ident.. SW F-test	8.17***	8.15***	14.70***	17.81***
Weak indent. SW Chi-sq	22.69***	22.71***	40.47***	48.92***
N	233	231	249	251
# locations	116	115	124	125
# Countries	35	35	38	35

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors are presented in parentheses, are robust to heteroscedasticity and clustered by country. a: controls include the share of indirect exports, instead of the share of direct and indirect exports used in other regressions.

Constraint upon instrument calibration

Constrained instrument use a distance variable that only considers firms located >100km from the closest infrastructure nodes, and takes a value of zero otherwise.

	(1)	(2)	(3)	(4)
	Total sales	Sales / worker	Direct exports ^a	# of FT employees
Email use	2.557**	2.232***	-2.895	1.227***
	(1.120)	(0.762)	(10.19)	(0.452)
1st stage est.				
Sequake freq 100-500km x Ln dist infra	-0.0022*** (0.0006)	-0.0022*** (0.0006)	-0.0019** (0.0006)	-0.0021*** (0.0006)
Sequake freq 500-1000km x Ln dist infra	-0.0003 (0.0017)	-0.0003 (0.0017)	-0.0005 (0.002)	-0.0003 (0.002)
Fixed effects	Country, year, country-year, sector, region, location.			
Controls	Yes			
Hansen test p-value	0.54	0.64	0.04	0.21
Under-ident.. SW F-test	7.55***	7.55***	5.73***	7.55***
Weak indent. SW Chi-sq	20.73***	20.73***	15.72***	20.73***
N	251	251	251	251
# locations	125	125	125	125
# Countries	38	38	38	38

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors are presented in parentheses, are robust to heteroscedasticity and are clustered by country

Excluding mobile firms: large and foreign firms

	(1)	(2)	(3)	(4)
Var dep:	Total sales	Sales / worker	Direct exports ^a	# of FT employees
Email use	5.454*** (1.580)	3.921*** (1.117)	-1.884 (9.915)	0.608* (0.338)
1st stage est.				
Sequake freq 100-500km x Ln dist infra	-0.0018** (0.0008)	-0.0018** (0.0008)	-0.0017** (0.0008)	-0.0026*** (0.0006)
Sequake freq 500-1000km x Ln dist infra	-0.0046*** (0.0016)	-0.0046* (0.0016)	-0.0044*** (0.0015)	-0.0039*** (0.0014)
Fixed effects	Country, year, country-year, sector, region, location.			
Controls	Yes			
Hansen test p-value	0.66	0.44	0.71	0.42
Under-ident.. SW F-test	4.04**	4.04**	4.04**	4.04**
Weak indent. SW Chi-sq	10.98***	10.98***	10.99***	4.04***
N	251	251	251	251
# locations	125	125	125	125
# Countries	38	38	38	38

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors are presented in parentheses, are robust to heteroscedasticity and clustered by country. a: controls include the share of indirect exports, instead of the share of direct and indirect exports used in other regressions.

Excluding seaquakes close to the coast

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Var dep:	Total sales		Sales / worker		Direct exports		# of FT employees	
Email use	2.276*** (0.873)	2.617*** (0.769)	2.014*** (0.706)	2.306*** (0.672)	9.799 (9.178)	11.751 (10.59)	1.203** (0.519)	1.141** (0.552)
1st stage est.								
Sequake freq 1000km rad > 50km from the coast x Ln dist infra	-0.0024*** (0.0008)		-0.0024*** (0.0008)		-0.0020*** (0.0007)		-0.0022*** (0.0007)	
Sequake freq 500km rad > 50km from the coast x Ln dist infra,		-0.0020*** (0.0008)		-0.0020*** (0.0007)		-0.0017*** (0.0006)		-0.0018*** (0.0006)
Fixed effects	Country, year, country-year, sector, region, location.							
Controls	Yes							
Under-ident.. SW F-test	9.78***	8.82***	9.78***	8.82**	9.22***	8.38***	10.91***	10.21***
Weak indent. SW Chi-sq	13.52***	12.19***	13.52***	12.19***	12.68***	11.53***	15.00***	14.04***
N	219	219	219	219	229	229	229	229
# locations	109	109	109	109	114	114	114	114
# Countries	31	31	31	31	33	33	33	33

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors are presented in parentheses, are robust to heteroscedasticity and clustered by country. a: controls include the share of indirect exports, instead of the share of direct and indirect exports used in other regressions.

Excluding firms located in capital cities.

	(1)	(2)	(3)	(4)
Var dep:	Total sales	Sales / worker	Direct exports ^a	# of FT employees
Email use	3.316*** (0.703)	3.062*** (0.6537)	1.558 (7.035)	0.896 (0.568)
1 st stage est.				
Seaquake freq 100-500km x Ln dist infra	-0.0025*** (0.0006)	-0.0025*** (0.0006)	-0.0024** (0.0008)	-0.0024*** (0.0006)
Seaquake freq 500-1000km x Ln dist infra	-0.0026 (0.0022)	-0.0026 (0.0022)	-0.0027 (0.0023)	-0.0030 (0.0021)
Fixed effects	Country, year, country-year, sector, region, location.			
Controls	Yes			
Hansen test p-value	0.70	0.73	0.82	0.60
Under-ident.. SW F-test	10.92***	10.92***	11.60***	10.37***
Weak indent. SW Chi-sq	30.69***	30.69***	32.62***	28.96***
N	235	235	106	249
# locations	117	117	53	124
# Countries	38	38	18	41

Note: * significant at 10%, ** significant at 5%, *** significant at 1%. Control estimates not reported. Standard errors in parentheses are robust to heteroscedasticity and clustered by country. a: controls include the share of indirect exports, instead of the share of direct and indirect exports used in other regressions.

Summary of main results

		(ln) Total sales	(ln) Sales per worker	(ln) # FT employees	% direct exports
(A) IV baseline estimations	Coefficient	3.690***	2.607***	1.156***	3.152
	Std error	0.906	0.573	0.389	4.977
(B) Excluding outliers.	Coefficient	3.005***	2.201***	1.156***	5.093
	Std error	0.855	0.769	0.388	4.672
(C) Excluding large and foreign firms.	Coefficient	5.454***	3.921***	0.608*	-1.884
	Std error	1.58	1.117	0.338	9.915
(D) Excluding seaquakes close to the coast.	Coefficient	2.276***	2.014***	1.203**	9.799
	Std error	0.873	0.706	0.519	9.178
(E) Constrained instruments.	Coefficient	2.557**	2.232***	1.227***	-2.895
	Std error	1.12	0.762	0.452	10.19
(F) Capital cities	Coefficient	3.316***	3.062***	0.896	1.558
	Std error	0.703	0.6537	0.568	7.035
(G) Excluding landlocked countries.	Coefficient	4.601***	2.752***	1.345***	4.684
	Std error	0.997	0.717	0.271	3.951
(H) Municipalities	Coefficient	2.337***	1.704***	1.186***	0.008
	Std error	0.920	0.6537	0.201	4.729

Disentangling the Internet-employment nexus

- We use data on the workforce composition in manufacture firms.
- Estimations also point to a positive effect of email use on the (ln) **number of production workers** and **non-production workers**, with a stronger effect on the former.
- The effect on production workers appears to be driven by the unskilled production workforce. Estimates robust to previous sample restrictions.

	Var dep:	(1)	(2)	(3)	(4)
		Workers		Prod. Workers	
		Non prod.	Prod.	skilled	unskilled
Email use		2.197*** (0.722)	3.510*** (1.045)	0.085 (0.691)	4.123*** (1.448)
1st stage est.					
Seaquake freq 100-500km x Ln dist infra		-0.0023*** (0.0005)	-0.0023*** (0.0005)	-0.0023*** (0.0006)	-0.0023*** (0.0006)
Seaquake freq 500-1000km x Ln dist infra		-0.0026* (0.0014)	-0.0026* (0.0014)	-0.0027* (0.0014)	-0.0027* (0.0014)
Fixed effects		Country, year, country-year, sector, region, location.			
Controls		Yes			
Hansen test p-value		0.46	0.46	0.25	0.25
Under-ident.. SW F-test		8.47***	8.47***	8.47***	8.47***
Weak indent. SW Chi-sq		23.13***	23.13***	23.13***	23.13***
N		255	255	255	255
# locations		127	127	127	127
# Countries		38	38	38	38
# aggregated firms		32,880			

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Results

Conclusion

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Var dep:	Domestic SMEs				Excluding landlocked countries			
	Workers		Prod. workers		Workers		Prod. workers	
	Non prod	Prod	skilled	unskilled	Non prod	Prod	skilled	unskilled
Email use	0.565 (0.616)	0.670 (1.020)	-2.634*** (1.093)	3.130** (1.489)	2.736* (1.644)	4.981** (2.494)	2.439 (2.183)	5.018 (3.172)
1 st stage est.								
Seaquake freq 100-500km x Ln dist infra	-0.0017*** (0.0006)	-0.0017*** (0.0006)	-0.0017** (0.0006)	-0.0017** (0.0006)	-0.0018*** (0.0008)	-0.0018*** (0.0008)	-0.0018*** (0.0008)	-0.0018*** (0.0008)
Seaquake freq 500-1000km x Ln dist infra	-0.0037* (0.0013)	-0.0037* (0.0013)	-0.0037*** (0.0013)	-0.0037*** (0.0013)	-0.0029 (0.0026)	-0.0029 (0.0026)	-0.0029 (0.0026)	-0.0029 (0.0026)
Fixed effects	Country, year, country-year, sector, region, location.				Country, year, country-year, sector, region, location.			
Controls	Yes				Yes			
Hansen test p-value	0.79	0.12	0.66	0.65	0.13	0.13	0.13	0.13
Under-ident.. SW F-test	5.52***	5.52***	5.52***	5.52***	2.75*	2.75*	2.75*	2.75*
Weak indent. SW Chi-sq	14.93***	14.93***	14.93***	14.93***	9.40***	9.40***	9.40***	9.40***
N	255	255	255	255	104	104	104	104
# locations	127	127	127	127	53	53	53	53
# Countries	38	38	38	38	17	17	17	17
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Var dep:	Excluding firms located in capital cities				Excluding firms located in provinces			
	Workers		Prod. workers		Workers		Prod. workers	
	Non prod	Prod	skilled	unskilled	Non prod	Prod	skilled	unskilled
Email use	2.054** (0.978)	2.807** (0.903)	0.354 (1.847)	3.050* (1.670)	1.162 (1.644)	3.428** (1.634)	0.186 (1.847)	6.514*** (2.163)
1 st stage est.								
Seaquake freq 100-500km x Ln dist infra	-0.0023*** (0.0007)	-0.0023*** (0.0007)	-0.0023*** (0.0006)	-0.0023*** (0.0006)	-0.0014** (0.0006)	-0.0014** (0.0006)	-0.0014** (0.0006)	-0.0014** (0.0006)
Seaquake freq 500-1000km x Ln dist infra	-0.0032 (0.0026)	-0.0032 (0.0026)	-0.0032 (0.0026)	-0.0032 (0.0026)	-0.0012 (0.0026)	-0.0012 (0.0026)	-0.0012 (0.0026)	-0.0012 (0.0026)
Fixed effects	Country, year, country-year, sector, region, location.				Country, year, country-year, sector, region, location.			
Controls	Yes				Yes			
Hansen test p-value	0.45	0.45	0.22	0.55	0.58	0.58	0.48	0.48
Under-ident.. SW F-test	10.00***	10.00**	10.00**	10.00**	6.75**	6.75**	6.75**	6.75**
Weak indent. SW Chi-sq	28.21***	28.21***	28.21***	28.21***	20.73***	20.73***	20.73***	20.73***
N	233	233	233	233	177	177	177	177
# locations	116	116	116	116	88	88	88	88
# Countries	38	38	38	38	35	35	35	35

Additional results:

- Estimations also point to a positive effect of email use on the (ln) **number of production workers** and **non-production workers**, with a stronger effect on the former.
- Results are robust to alternative instrument calibrations:
 - ☐ Seaquake freq 100-1000km x Ln dist infra (best instrument but no Hansen test)
 - ☐ Seaquake freq [0-100km; 100-500km; 500-1000km] x Ln dist infra
 - ☐ Seaquake freq 100-1000km x Ln dist [SMC; IXP]
- Results are robust to alternative var. of Internet access: How access to telecommunications is an obstacle to firm operations? (no obstacle → very severe obstacle).
- Results are robust to the exclusion of firms located in capital cities from the sample.
- Results are robust to the exclusion of firms in the top 1% distributions of total sales and sales per worker.

Conclusion

- **Large effects of Internet use at the location level**, and therefore, suggests that the impact of broadband arrival is **heterogeneous within countries**.
- These positive effects appear to be mainly **driven by productivity gains** and the **services sector**.
- Our results specifically stress the **pb of a country's exposure to seismic risk** for the Internet economy's expansion and the performance of firms
- but **this conclusion can be extended to other sources of cable faults**, such as maritime activities, piracy, or other natural hazards.

Malecki (Econ Geo, 2002, p.399) on the Internet infrastructure:

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



Thank you!