

Spatial internet spillovers in manufacturing*

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Abstract

In this paper, we study the spatial spillover effects of internet usage on manufacturing output. Using repeated cross-section datasets of 40,154 manufacturing firms located in 91 developing and transition economies, we adopt an original shift-share instrumental variable set-up, and find that a greater diffusion of email technology in locations increases manufacturing firm's sales and productivity. This result is driven by local email dissemination within industries, supporting the existence of network or knowledge spillover effects among proximate firms, engaged in similar or interlinked activities. By contrast, the dissemination of email technology across other industries located in the same place reduces manufacturing firms' performance. However, these inter-industry spillovers are U-shaped, indicating that they remain negative below a local email incidence threshold established at approximately 50% of the local universe of firms, and turn positive only once this threshold is reached. Last, we find that positive Internet spillovers are mediated by firm's own use of the internet technology, and by its absorptive capacity, reflected by its share of skilled production workers, its multi-plant status, and its maturity.

Keywords: Connectivity, internet, spillovers, manufactures, industrialisation.

JEL classification: F61, L25, O33, O14, O18.

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1 Introduction

Constraints on economic interactions are particularly acute in many developing countries, where hard infrastructures are often missing and market imperfections are widespread. By reducing transaction costs and improving firms' production and organisation processes (Aker, 2017; Goldfarb & Tucker, 2019), digital technologies have thus become essential to the conduct of business in both high- and lower-income countries.¹ Beyond the benefits derived by the firms themselves from the adoption of such technologies, their dissemination in their proximate environment may also indirectly affect firms' activity.

In fact, a greater diffusion of digital technologies, such as the Internet, within an industry or a geographical area can generate positive spillover effects on the activity of firms belonging to these sets via network effects or digital knowledge spillovers (Paunov & Rollo, 2015, 2016; Marsh, Rincon-Aznar, Vecchi, & Venturini, 2017). Such externalities are inherent to digital technologies' status as general purpose technologies and network goods - their applications and related knowledge tend to spread across firms and industries - and the benefits increase with the size of the users' network (Katz & Shapiro, 1985; Bresnahan & Trajtenberg, 1995; Crémer, Rey, & Tirole, 2000; Björkegren, 2019). However there is also a risk with digitalisation² that it may primarily benefit first adopters (also coined "first-movers") or dominant firms at the expense of less performing firms with limited absorptive capacity (Görg & Greenaway, 2004; Marsh et al., 2017), of pushing forward the most advanced sectors of the economy to the detriment of the more traditional ones (Hjort & Poulsen, 2019; Rodrik, 2018; Choi, Dutz, & Usman, 2020). The digitalisation process could hence contribute to or accelerate the decline in certain industries and even assist in the de-industrialisation of economies (Rodrik, 2016a, 2016b, 2018). Therefore, the net economic benefits drawn from the diffusion of digital technologies are likely but not guaranteed.

The uncertainty over the digital dividends is particularly salient for firms operating in the manufacturing sector, especially those located in developing countries. While there is strong evidence of the positive effect of digitalisation on the service sector, at both the micro-level (Kneller & Timmis, 2016) and the macro-level (Freund & Weinhold, 2002), it is much less clear whether this process has benefited the manufacturing sector (Stiroh, 2002). Second, evidence on the consequences of the manufacturing sector's digitalisation is widely documented for industrialised countries, but rather scarce in the case of developing ones.³ Yet, the manufacturing sector is at the core of the industrialisation process, and thereby, identified as a critical source of income and job creation in developing countries, but is also the sector where technological absorptive capacity is particularly heterogeneous across firms (Tybout, 2000; Rodrik, 2016a, 2018). A better understanding of the contribution of internet technologies to manufacturing firms' performance is therefore of utmost importance for developing countries that are caught in an under-industrialisation trap or are suffering from premature de-industrialisation (Rodrik, 2016b; Diao,

¹Goldfarb and Tucker (2019) define digital technologies, of which internet technologies are part, as "the representation of information in bits [...] rather than atoms", which "reduces the cost of storage, computation and transmission of data" (p.3).

²In this paper, digitalisation refers to the growing use of digital technologies in the conduct of business.

³Paunov and Rollo (2015) address this issue, but in a very succinct way. They identify larger returns to email diffusion within industries for service firms than for those operating in the manufacturing sector.

McMillan, & Rodrik, 2019). Moreover, while recent studies have addressed the direct impact of firms' adoption of internet technology on their performance in low-income countries (see for instance Cariolle et al, 2019; Hjort & Poulsen, 2019; IMF, 2020), less is known about the indirect effect of the local diffusion of internet technology in developing areas. This paper contributes to the literature by estimating the spatial internet spillover effects – resulting from the spatial diffusion of email technology – on the performance of firms in the manufacturing sector, in a large sample of developing and transition economies.

An additional contribution of this paper comes from our identification strategy, which is meant to address two statistical challenges. First, an individual firm's performance may affect overall local economic activity, and hence, neighbouring firms' inclination to adopt emails, through for instance imitation behaviours. Such a mechanism could be a source of reverse causality bias. Second, omitted variables, especially unobserved local conditions, may influence both the firm's performance and the local diffusion of internet technologies. To address these endogeneity concerns, we adopt a quasi-experimental shift-share instrumental variable (SSIV) (Borusyak, Hull, & Jaravel, 2018). The incidence of email adoption among firms at the location level, which measures the local internet spillover effects, is instrumented by a set of SSIVs reflecting firms' exposure to aggregate variations in international connectivity. Importantly, this SSIV framework includes country-year, location, and industry fixed-effects, which strongly reduce concerns over an omitted variable bias.

Our empirical analysis combines firm-level data, drawn from the World Bank Enterprise Surveys (WBES), with data on the rollout of telecommunications submarine cable (SMC) infrastructures from Telegeography and an original event study on SMC faults. Our baseline estimation sample comprises 40,154 manufacturing firms, surveyed between 2006 and 2018 in 11 survey waves, located in 521 cities or regions, and spread across 91 developing and transition economies. Our results support the hypothesis that the local diffusion of internet technology in the manufacturing sector generates substantive positive internet spillovers in terms of revenue and productivity, thereby contributing to industrialisation in developing and transition economies. However, the examination of possible nonlinearities reveals U-shaped inter-industry spillovers, meaning that the local use of the Internet needs to reach a critical mass to generate positive effects across manufacturing industries. Moreover, we find that positive geographical internet spillovers are conditional on firms' own adoption of the internet technology, and on firms' absorptive capacity (measured by their share of skilled production workers, their multi-plant status, and their maturity). These results taken as a whole suggest that a delay is required in order to reap the benefits of email diffusion across industries (Marsh et al., 2017): in the short-run, email incidence is limited and therefore benefits the highest performing firms with the greatest absorptive capacity, while in the longer run, this diffusion gets larger and benefits the entire local economy. As time goes on and as internet use spreads locally and across industries, it may increasingly benefit manufacturing firms and spur industrialisation.

The next section sets out our analytical framework and the related literature review. The third section exposes our empirical framework, while the fourth section presents our main findings. Robustness checks are performed in the fifth section. The sixth section concludes.

2 Internet spillovers and industrialisation: analytical framework

An important aspect of the digitalisation-industrialisation nexus that has been partially or fully overlooked by previous studies is the indirect consequences of a greater diffusion of digital technologies, also coined *digital spillovers*, on developing countries' manufacturing sector. Because of the general purpose nature of digital technologies and their network-based functioning, their diffusion may spur economic transformations that go beyond the direct effects of their adoption.

First, positive digital spillovers may result from *network effects* induced by a higher penetration of digital technologies among firms, which leads to the multiplication and acceleration of interactions between adopters (Stiroh, 2002; Grace, Kenny, & Qiang, 2003). ICTs are indeed network goods whose derived benefits depend on the adopter's network size (Katz & Shapiro, 1985; Crémer et al., 2000; Grace et al., 2003; Marsh et al., 2017; Björkegren, 2019). The greater the number of users of a digital technology in a given location or given industry, the greater the socio-economic benefits derived from its adoption.

Second, there are also *knowledge spillovers* resulting from the sharing of information, the imitation of good practices and processes, and the dissemination of innovations through ICT diffusion (B. Harrison, Kelley, & Gant, 1996; Frenken, Van Oort, & Verburg, 2007; Corrado, Haskel, & Jona-Lasinio, 2017; Paunov & Rollo, 2015, 2016). Knowledge spillovers fall within two categories (Marsh et al., 2017): on the one hand, the knowledge originating from competitors, also called within-industry or *intra-industry spillovers*, and on the other hand, the knowledge created from outside the industry, also called cross-industry or *inter-industry spillovers*. While the first type of knowledge spillovers has been coveted extensively in theoretical and empirical research, the second type of information spillovers is much less documented. It suggests that the creation and circulation of knowledge spread across industries, when for instance upstream and downstream industries communicate, exchange, replicate, or adapt ideas, processes and business practices (Marsh et al., 2017).

Third, negative internet spillovers may prevail if the increased use of related digital technologies by other firms translate into greater competition, which in turn may translate into revenue losses for firms with limited technology absorptive capacity (Görg & Greenaway, 2004; Marsh et al., 2017). This limited absorptive capacity can be explained by a lack of digital skills within the firm, by the delayed diffusion of positive digital technologies within industries, by a low exposure to international competition, or by limited research and development (*R&D*) activities. Moreover, the diffusion of digital technologies and related knowledge across industries may also spur structural change, causing the decline of traditional industries using obsolete technologies or made obsolete by technological shift (McMillan, Rodrik, & Sepulveda, 2016; Choi et al., 2020; Diao et al., 2019).

In this paper we focus on spillover effects generated by the diffusion of the internet. The propagation of the internet constitutes only one element of the digitalisation process but is probably one of the most significant, and may lead to all the side effects described above.

3 Empirical framework

3.1 Model

To estimate the causal effect of local internet diffusion on manufacturing firms' performance, our IV approach consists in estimating the following second-stage and first-stage equations:

$$Y_i = \alpha_0 + \alpha_1 \cdot \overline{Internet}_{l(i)t(i)} + \alpha_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \varepsilon_{1i} \quad (1a)$$

$$\overline{Internet}_{l(i)t(i)} = \beta_0 + \beta_1 \cdot Z_{l(i)t(i)} + \beta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \varepsilon_{2l(i)t(i)} \quad (1b)$$

Where the subscripts i , j , k , l , and t respectively refer to the firm, country, industry, location, and year of the survey, Y_i is a variable measuring the performance of the firm, $\overline{Internet}_{l(i)t(i)}$ measures the spatial internet spillovers reflected by the incidence of email use at the location level at time t . $Z_{l(i)t(i)}$ represents the set of instruments and X_i is a set of firm-level characteristics. These equations also include country-year ($d_{j(i)t(i)}$), industry ($d_{k(i)}$), location dummies ($d_{l(i)}$), and random error terms (ε_i). Standard errors are robust to heteroscedasticity and clustered at the country-year level.

3.2 Data and descriptive statistics

The variables used in our standard model are drawn from the standardised World Bank Enterprise Surveys (WBES). These surveys provide repeated cross-sectional data, covering an original representative sample (random stratified sampling) of the whole non-agricultural and urban private sector in developing and transition countries. Our sample covers some 40,000 manufacturing firms from 521 locations (cities or regions) in 91 developing and transition countries, surveyed over the period 2006-2018. In each country, data were gathered using an extensive and internationally comparable questionnaire administered via face-to-face interviews with business owners and senior managers.

3.2.1 Firms' performance (Y_i).

To measure the performance of a firm we use two manufacturing output variables. First, we use the logarithm of the firm's total annual sales (in USD, logarithmic), as a measure of the firm's market outreach. Second, we use the logarithm of the firm's total sales per full-time permanent worker adjusted for temporary workers (in USD, logarithmic), to measure labour productivity, as commonly used in the literature (Chemin, 2020; Léon, 2020).

3.2.2 The spatial diffusion of email technology ($\overline{Internet}_{l(i)t(i)}$).

The diffusion of internet technology is proxied by the incidence of email use among both manufacturing and service firms, in the location (city or region) where the firm operates. We focus on emails since this technology reflects one of the most basic and widespread uses of digital technology in the private sector worldwide, with probably the greatest impact on firms' outcomes. When firms declare that they use

email, this means that they are connected to the internet, either through an internet service provider or a mobile operator, and that they can also have access to information on prices, on competitors, etc. through internet searches. Moreover, this variable has the advantage of reflecting the use of internet technology for internal organisational issues and for communication with external entities (clients, suppliers, other firms or administrations).

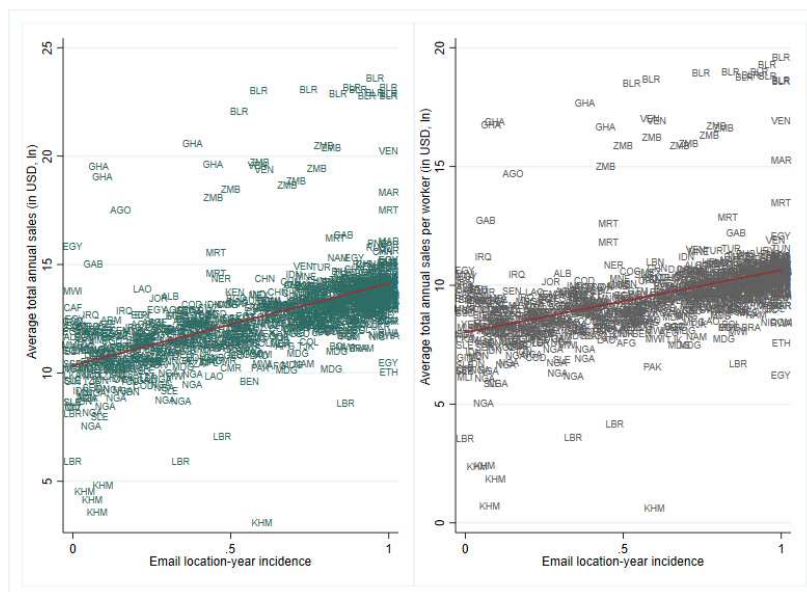
Therefore, we compute for each survey-round the average rate of email use at the location level, as follows:

$$\overline{Internet}_{l(i)t(i)} = \frac{1}{N_l - 1} \left(\sum_{f \in l} Email_{f,l} - Email_{i,l} \right) \forall l \in L, i \neq f \quad (2)$$

Where *Email* is a dichotomous variable indicating whether firms *i* and *f* in location *l* use email for the conduct of business - or not -. *L* refers to the sets of locations *l* where the firms operate, and *N_l* refers to the respective number of firms in each location *l*. This incidence variable is computed excluding manufacturing firm *i*'s own adoption of email technology to address eventual reverse causality bias, and therefore, exhibits firm-level variability. Moreover, it is necessary to separate the direct effect of a firm's individual decision to adopt email technology (included as a control variable), from the spillover effects of its diffusion at the location-level.

Figure 1 graphically represents the simple correlation of email incidence with firms' development outcomes, and supports the hypothesis that there is a strong positive relationship between email incidence and firms' output and productivity.

Figure 1: Location email incidence and manufacturing firms' performance.



Source: WBES data and authors' calculation based on 868 pooled observations (650 locations from 120 countries).

3.2.3 Control variables

Previous graphical evidence may be the result of confounding factors, correlated with both email diffusion and firms' performance. To neutralise their influence, we control for a set of firm-level characteristics whose impact on performance has been evidenced in the literature (Dollar, Hallward-Driemeier, & Mengistae, 2005; Paunov & Rollo, 2015, 2016). To separate the effect of individual adoption of email technology from the spillover effects caused by its local diffusion, we control for email and website adoption. We also control for the size and composition of the workforce, measured by the number of full-time permanent employees when the firm started operations, the share of non-production workers in the total workforce, and the share of skilled workers among production workers. Since management quality may be an important determinant of the firm's absorptive capacity, we control for the firm's maturity, proxied by the firm's age (in years) and its top manager's experience (in years). We control for determinants of the firm's performance such as its public and foreign ownership structure, its degree of export orientation, and its financial liabilities (measured by a dummy equal to one if the firm has a credit line or a loan from a financial institution). Since access to internet relies on access to energy, we take into account the firm's electricity constraint, as reported by the firm.⁴ Last, our set of control variables also comprises the geographical distance to the closest international connectivity infrastructure – i.e. the closest submarine cable (SMC) landing stations or Internet Exchange Point (IXP) in the country where the firm operates.⁵ Summary statistics of standard WBES variables used in regression analysis are reported in Table 1 below.

3.3 Shift-share instrumental variable approach

To estimate the causal effect of email incidence on manufacturing firms' performance in developing countries, we adopt a quasi-experimental shift-share instrumental variable (SSIV) framework (Borusyak et al., 2018). In this approach, instrumental variables are random aggregate connectivity shocks weighted by a possibly-endogenous factor reflecting firms' exposure to them.

3.3.1 Aggregate connectivity shocks

Our instrument set combines two interdependent sources of variation in aggregate connectivity, related to the deployment of telecommunication submarine cables (SMCs): i) the SMC network's size, and ii) the country's experience of SMC outages and the duration of the associated repairs.

SMC network size. SMCs are the corner stone of the worldwide telecommunications network. The exponential rise in their deployment over time has led to a dramatic increase in the worldwide telecommunications network's size, capacity, and redundancy, especially in developing countries. Figure 2 illustrates

⁴This control is an ordered categorical variable: firms were asked whether access to electricity is i) not an obstacle, ii) a minor obstacle, iii) a moderate obstacle, iv) a major obstacle, or v) a very severe obstacle to their operations

⁵Raw data on SMC landing stations and Internet Exchange Points' status (active/inactive/project), year of activation, and GPS coordinates are drawn from Telegeography and completed by the Packet Clearing House and Peering DB databases. If a country does not host any SMC or IXP, the distance is calculated with respect to the closest infrastructure in neighbouring countries.

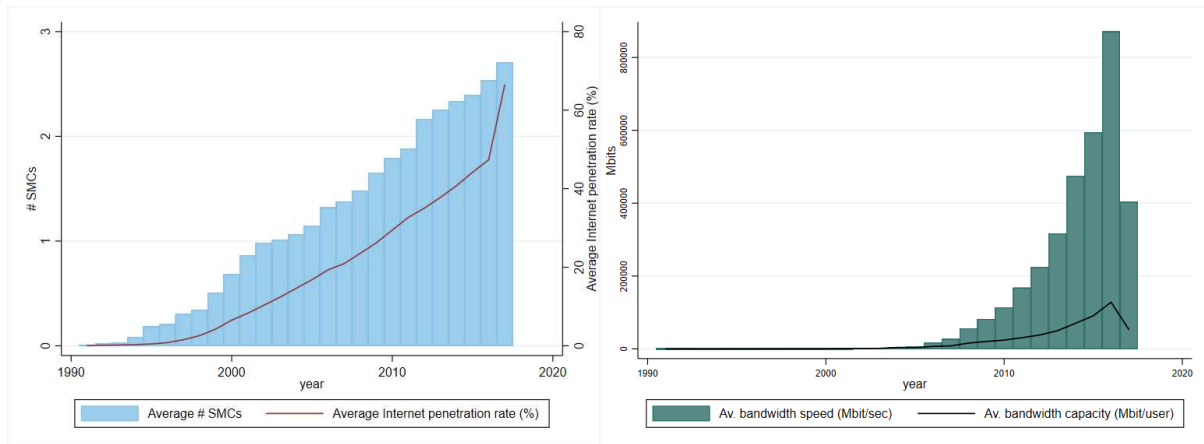
Table 1: Summary statistics of WBES variables.

Variables	Mean	Std. Dev.	Min	Max
Firm outcomes (Y_i)				
Real annual sales (USD, ln)	13.30	2.56	0	27.19
Real annual sales / worker(USD, ln)	9.87	1.95	0	21.90
Internet spillovers ($\overline{Internet}_{l(i)t(i)}$)				
Email location incidence [0;1]	0.72	0.25	0	1
Control variables (X_i)				
Email adoption (0 or 1)	0.72	0.45	0	1
Website adoption (0 or 1)	0.45	0.50	0	1
% of state ownership	0.51	5.77	0	100
Distance to connectivity infra (km, ln)	4.65	2.00	0.69	8.35
% of foreign ownership	6.55	22.9	0	100
% dir. indir. Exports in sales	12.46	27.50	0	100
Firm's age (years, ln)	2.74	0.70	0	4.76
Initial # perm. FT employees(ln)	2.69	1.25	0	13.82
Share non-production workers in total workforce	0.70	0.31	0	1
Share skilled workers in production workforce	0.25	0.17	0 <td 1	
Manager experience (years, ln)	2.66	0.75	0	4.31
Bank loan (0 or 1)	0.38	0.48	0	1
Electricity obstacle (ordered, 0 to 4)	1.79	1.49	0	4

Sample: 40,154 manufactures from 521 locations (cities/regions) in 91 developing and transition countries.

this trend by representing the strong increase in the internet connectivity – measured by the internet penetration rate and the average international internet bandwidth per user – that followed the connection of developing countries to the world SMC network. As a result, SMC rollout is expected to boost internet speed, capacity and affordability, thereby increasing the likelihood of internet adoption and diffusion across firms, locations, and industries. Therefore, variations in the number of SMCs laid in a given country can be considered as an exogenous source of variation in connectivity, which is expected to boost firm performance through improved access to internet. This exogeneity claim is realistic provided aggregate determinants of SMC arrival are controlled for, which is done through country-year fixed effect inclusion.

Figure 2: Internet connectivity and international bandwidth in developing countries (1990-2016).



(a) Internet connectivity.

(b) International bandwidth.

Source: Authors, based on data from ITU (2019) and Telegeography's submarine cable map: <https://www.submarinecablemap.com/>.

SMC faults. Second, SMC outages, caused by humans (sabotage, maintenance), maritime activities (anchors and fishing nets) or natural hazards (typhoons, earthquakes, turbidity currents), are also a source of variation in aggregate connectivity, as they reduce the capacity and stability of the telecommunications network (Carter, 2010, 2014; Pope, Talling, & Carter, 2017; Aceto, Botta, Marchetta, Persico, & Pescapé, 2018). Moreover, in addition to the direct economic and welfare costs related to telecommunication shut-downs, SMC outages induce expensive repairs, higher insurance costs, and costs related to the re-routing of Internet traffic towards more expensive and lower-capacity cable paths. Importantly, these direct and indirect costs are amplified by the time needed for cable repairs (Carter, 2010; Palmer-Felgate, Irvine, Ratcliffe, & Bah, 2013; OECD, 2014). Our SSIV therefore exploits country-level variations in cumulated cable repair time, reflecting both the recurrence and duration of adverse shocks incurred by the SMC network.

This has been done by building an original database documenting the occurrence of SMC-induced Internet disruptions by country and year, the cause of these outages, as well as the duration (in days) of cable repairs, over the 2005-2020 period.⁶ Due to possible endogeneity concerns, we drop all observations from the sample that include a cable outage induced by natural hazards (earthquake, hurricanes, floods). For the same reason, we also drop observations where reported internet disruptions are suspected to have been caused by a government intervention.⁷ In our estimation sample, 30 out of 91 countries have experienced Internet disruptions caused by SMC faults, during the current and four years preceding the survey wave (Table 2). Among these countries, India’s SMC network has been hit four times over ($t; t - 4$) and has undergone 33 cumulated days of repair, while Sri Lanka experienced two Internet disruptions associated with 56 days of repair.

Distance to connectivity infrastructure and firm’s exposure to connectivity shocks. Our SSIV design assumes that the firms’ exposure to SMC connectivity shocks depends on their distance to the closest international connectivity infrastructures, that is, SMC landing stations and Internet Exchange Points (IXPs). In fact, studies have shown that populations remote from backbone infrastructures often suffer from slower and unstable telecommunications (Gorman, Schintler, Kulkarni, & Stough, 2004; Grubestic & Murray, 2006; Buys, Dasgupta, Thomas, & Wheeler, 2009). Since the WBES dataset includes information on the location of observational units (city or region), we use the distance from the firm’s location to international connectivity infrastructures, i.e. SMC landing stations or Internet Exchange Points, as a shock weighting factor.⁸ Since this weighting factor exhibits time variation, due to the rollout

⁶Primary raw data on outage time, duration and source has been drawn and treated from the Subtel forum: <http://subtelforum.com/category/cable-faults-maintenance/>. It has been completed with information drawn from Akamai reports on the “State of Internet connectivity” covering the 2008-2017 period, as well as manual Internet searches.

⁷Cariolle, Le Goff, and Santoni (2019) use the countries’ exposure to seaquakes occurring in the vicinity of SMC landing station as an aggregate connectivity shock variable. They address the concern regarding over-identification by placing constraints upon the seaquake’s magnitude and imposing a minimum distance between the seaquake’s epicentre and the landing station.

⁸Taking the firm’s city centroid as geographical coordinate. When the geographical stratification unit is the region or a group of cities, which sometimes happens in the dataset, we take the region’s or city group’s centroid as geographical coordinate.

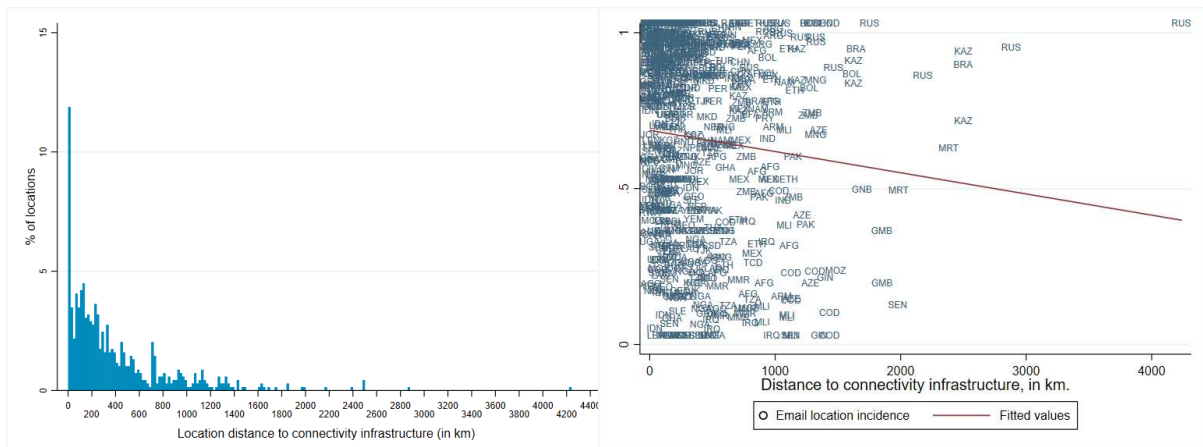
Table 2: Internet disruptions and repair duration caused by SMC faults over $(t; t - 4)$, estimation sample.

iso	Σ disruptions	Σ repairs days	iso	Σ disruptions	Σ repairs days
ARM	1	1	KEN	3	26
BDI	2	16	LBN	2	13
BEN	1	15	LBR	1	2
BGD	3	9	LKA	2	56
CHN	3	5	MMR	1	20
CMR	3	10	MYS	1	1
COL	1	2	NGA	3	37
DJI	2	22	PAK	3	29
ECU	1	1	PHL	3	53
ETH	1	7	SLE	2	8
GEO	1	1	TZA	1	10
IDN	1	49	YEM	2	12
IND	4	33	ZMB	1	12
JOR	1	1	Total	50	451

Source: Authors' calculation. Data drawn from the Subtel forum <http://subtelforum.com/category/cable-faults-maintenance/>, Akamai's reports on the "State of Internet connectivity", and completed by manual Internet searches.

of SMCs and IXPs over time, it is important to include this distance variable alone as additional control (Borusyak et al., 2018). Figure 3a shows the distribution of this distance variable across locations in our baseline estimation sample. Figure 3b plots a negative correlation between the sample locations' distance to connectivity infrastructures and the incidence of email use at the location level.

Figure 3: Location distances to international connectivity infrastructures (SMCs or IXPs): sample distribution and correlation with email incidence.



(a) Sample distribution.

(b) Correlation with location email incidence.

3.3.2 Instrumental variables

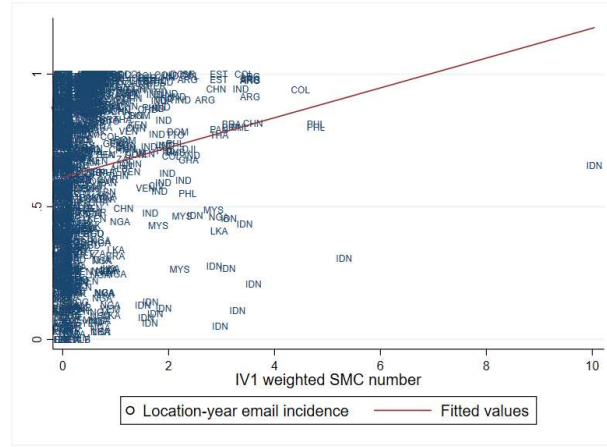
Overall, our SSIV strategy consists in weighting two main sources of aggregate connectivity shocks – the number of SMCs laid in a given country and the cumulated duration of SMC repairs – by the distance from the location to the closest internet connectivity infrastructure. As a result, we obtained two IVs, exhibiting location-year variability after the inclusion of country-year fixed effects. The first instrument

(IV1) reflects the firm's SMC network connectivity, calculated as follows:

$$IV1_{l(i)t(i)} = SMCnum_{j(i)} \times \frac{1}{1 + \ln(1 + Distance_{l(i)t(i)})} \quad (3)$$

Where $SMCnum_{j(i)}$ is the number of SMCs laid in country j and $Distance_{l(i)t(i)}$ is the distance from the firm's location to the closest connectivity infrastructure at time t . Figure 4 below represents graphically the correlation between this instrument and the incidence of email use at the location level. As expected, the number of SMCs to which locations are connected ($IV1_{l(i)t(i)}$), which is supposed to improve the quality of the Internet connexion, is strongly positively associated with email incidence at the location level.

Figure 4: Correlation between IV1 and email incidence.



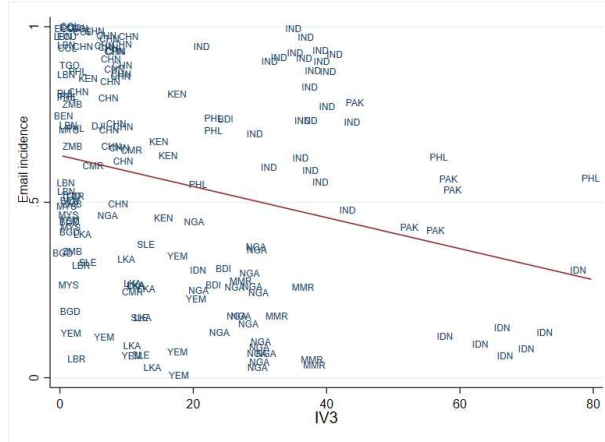
The second (IV_2) reflects firms' exposure to SMC-induced Internet disruptions and associated cable repair duration. Because shocks can have a lagging effect on the penetration of internet through a decrease in internet service quality and an increase in Internet tariffs, this IV is calculated over various time-windows going up to four years before the survey year, as expressed in Eq.(4):

$$IV2_{l(i)t(i)} = \frac{1}{1 + \tau_2 - \tau_1} \sum_{\tau=t-\tau_2}^{t-\tau_1} (Repair_days_{j(i)\tau(i)} \times [1 + \ln(1 + Distance_{l(i)\tau(i)})]) \quad (4)$$

Where $\tau_1 = [0; 3] \leq \tau_2 = [1; 4]$, $Repair_days_{j(i)\tau(i)}$ the cumulated number of days necessary to repair damaged cables in country j in year $(t - \tau)$, and $Distance_{l(i)\tau(i)}$ is the same weighting distance variable as in Eq.(3).

In the estimations, IV_2 's time windows are calibrated to optimise first-stage statistics. Below, Figure 5 illustrates the correlations between IV_2 , computed over $[t; t - 4]$, and the incidence of email use at the location level. Only correlations between observations with above-zero instrumental variable values are reported, since being exposed to connectivity shocks requires having at least one SMC connection. This graph illustrates the negative correlation between this instrument and location email incidence.

Figure 5: Correlation between IV2 and location-year email incidence.



3.3.3 Exclusion restrictions

To ensure our instrumental variable strategy do not violate exclusion restrictions, we take a number of precautions regarding the building of our instruments. First, we only consider SMC disruptions caused by humans (sabotage, maintenance) and maritime activities (anchors, fishing nets), and exclude those generated by government interventions and natural hazards (seaquakes, typhoons, etc.) that are likely to affect firms by a channel other than connectivity⁹. Note that regardless of whether the firm uses Internet via a computer or a mobile device, its connectivity will be similarly affected by SMC-related internet disruptions. Moreover, to control for country-level factors that could affect both connectivity at the local level and firms' performance, we include country-year fixed effects. Regarding the distance variable used as a weighting factor in our instrument set-up, Borusyak et al. (2020) show that its potential endogenous nature is not a concern. Nevertheless, because broadband infrastructures may be overrepresented in ports or in big cities for example, and because local unobserved heterogeneity could possibly affect manufacturers' performance and email use, we add location (city or region) fixed-effects to our model. Last, because big, multi-plant, foreign or exporting firms could be more mobile in their location choice, and therefore, choose to settle next to the internet connectivity infrastructures, we carry out robustness checks consisting in excluding these firms from our sample.

4 Empirical results

4.1 Baseline estimations

Table 3 reports the results of IV-2SLS pooled estimations of the baseline econometric model (Eq. (1)). First-stage test statistics confirm the validity and strength of the different instrument set parametrisations.¹⁰ As expected, the instrument based on the SMC network size (*IV1*) has a significant positive

⁹Without appropriate constraints placed on instruments calibration, as in Cariolle et al. (2019)

¹⁰Note that the reported Sanderson-Windmeijer multivariate F-test, applied to individual endogenous regressors, differs from the usual F-test when there are multiple endogenous regressors. In most regressions, this last statistic generally exceed

effect on location email incidence, while the instrument based on adverse connectivity shocks (*IV2*) has a significant negative effect. All instrument set calibrations respect identification restrictions, but the set with *IV2* computed over ($t; t - 4$) appears to have slightly better first-stage statistics than other calibrations.¹¹

Second-stage estimations first indicate a positive and significant effect of location email incidence on manufacturing firms' total sales and sales per worker, independent of the firms' use of email or website. According to our estimates, total sales are found to increase by 3.6 percentage point following a 1 percentage point increase in the local incidence of email. It is worth pointing out that this effect is of equal amplitude on sales per worker, suggesting that digital email spillovers tend to raise total sales while keeping the level of employment unchanged.¹² Such a pattern could be explained by an increase in the firm's local market outreach, resulting from a greater internet user network size.

Therefore, unlike studies that do not find evidence of ICT spillovers in industrialized countries (Stiroh, 2002; Cardona, Kretschmer, & Strobel, 2013; Acharya, 2016), and as opposed to the study conducted by Marsh et al. (2017) which stresses negative (intra-industry) ICT spillovers on US companies' productivity¹³, we highlight substantial positive spatial internet spillovers on manufacturing firms' performance in a large sample of developing and transition economies. However, we cannot yet determine whether this result is driven by intra-industry or inter-industry incidence of email. The next sub-section attempts to address this question.

4.2 Intra-industry *versus* inter-industry spillovers

A vast literature has stressed the existence of intra-industry spillovers, driven by *Marshall externalities* or *localisation economies* (between firms operating in the same industry or engaged in similar activities located at the same place), and inter-industry spatial spillovers, driven by *Jacob externalities* (between firms operating in diverse industries in a given location) as well as *urbanisation economies* (spillovers induced by urban size and density, but independent of established industries structure, diversity or complementarity) (Jacobs, 1969; Glaeser, Kallal, Scheinkman, & Shleifer, 1992; Kugler, 2006; Frenken et al., 2007; Nakamura, 2012; Marsh et al., 2017). Spillovers from ICTs, like other types of spillovers, follow this same distinction (Marsh et al., 2017). To study local internet spillover effects *within* and *across* industries, we decompose the location email incidence variable into:

- a variable measuring the spatial diffusion of email use among firms operating in the same industry as the firm considered, calculated as follows,

$$\overline{Email_intra}_{l(i)k(i)} = \frac{1}{N_{k,l} - 1} \left(\sum_{f \in k,l} Email_f - Email_i \right) \forall i \neq f, f \in K_l, l \in L$$

100, suggesting in a consistent way that our IV does not suffer from weak identification.

¹¹Estimations resulting from additional calibrations can be provided upon request.

¹²But this result does not exclude the possibility of a change in the workforce composition, in favour for instance of skilled labour, nor of a medium/long term effect on permanent employment.

¹³Turning positive in the long run.

Table 3: Baseline estimations.

	(1)	(2)	(3)	(4)
Dep. Var:	Total sales		Sales per worker	
$\overline{Internet}_{l(i)t(i)}$	3.867*** (0.734)	3.805*** (0.728)	3.619*** (0.711)	3.655*** (0.722)
Email adoption	0.648*** (0.098)	0.648*** (0.098)	0.647*** (0.099)	0.356*** (0.073)
Website adoption	0.655*** (0.056)	0.655*** (0.056)	0.655*** (0.056)	0.296*** (0.033)
	First-stage estimates			
IV1	0.183*** (0.058)	0.185*** (0.058)	0.190*** (0.058)	0.190*** (0.058)
IV2 – Calibrations: ($\tau_1 = 0$; $\tau_2 = 2$)	-0.008*** (0.003)			
($\tau_1 = 0$; $\tau_2 = 3$)		-0.010*** (0.004)		
($\tau_1 = 0$; $\tau_2 = 4$)			-0.0137*** (0.005)	-0.0137*** (0.005)
Weak-id SW F stat	118.33	119.40	125.62	125.62
Under-id SW Chi-2 stat.	241.91	244.11	256.81	256.81
Email adoption	0.648*** (0.098)	0.648*** (0.098)	0.647*** (0.099)	0.356*** (0.073)
Website adoption	0.655*** (0.056)	0.655*** (0.056)	0.655*** (0.056)	0.296*** (0.033)
Anderson-Rubin Wald F-stat	294.95	147.63	147.93	297.96
Hansen J test (P-val.)	0.196	0.197	0.197	0.552
Control variables (X_i)	Yes	Yes	Yes	Yes
Fixed effects ($d_{j(i)t(i)}$, $d_{l(i)}$, $d_{k(i)}$)	Yes	Yes	Yes	Yes
N	40,154	40,154	40,154	40,154
# Locations	521	521	521	521

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-year of survey.

- a variable measuring the spatial diffusion of email use among the universe of firms operating in the same location but in the remaining set of industries, calculated as follows:

$$\overline{Email_inter}_{l(i)k(i)} = \frac{1}{N_{-k,l}} \left(\sum_{f \in -k,l} Email_f \right), \forall f \in -K_l, l \in L$$

Where $N_{k,l}$ refers to the number of firms operating in industry k from location l , $N_{-k,l}$ represents the number of firms operating in other industries established in location l , K_l represents the set of industries k established in location l , and L is the set of locations l . The Survey-year subscript t is removed for the sake of simplification.

We therefore conduct 2SLS estimations of the following system of equations:

$$Y_i = \gamma_0 + \gamma_1 \cdot \overline{Internet_intra}_{l(i)k(i)} + \gamma_2 \cdot \overline{Internet_inter}_{l(i)k(i)} + \gamma_3 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \epsilon_i \quad (5a)$$

$$\overline{Internet_intra}_{l(i)k(i)t(i)} = \delta_0 + \delta_1 \cdot Z_{l(i)t(i)} + \delta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \epsilon_{2l(i)k(i)t(i)} \quad (5b)$$

$$\overline{Internet_inter}_{l(i)k(i)t(i)} = \zeta_0 + \zeta_1 \cdot Z_{l(i)t(i)} + \zeta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \epsilon_{3l(i)k(i)t(i)} \quad (5c)$$

Where $(\epsilon_{1i}, \epsilon_{2l(i)k(i)t(i)}, \epsilon_{3l(i)k(i)t(i)})$ is the error terms structure.

The results reported in Table 4 show conflicting local spillover effects, depending on whether digital technology diffusion has taken place within or outside the industry where the firm operates. On the one hand, we find that the incidence of email use in the same industry has a positive and significant effect on the firm's performance (sales and sales per worker). To ensure that our findings are not biased by the small sample size in specific locations-industries, we re-run estimations excluding location-industries with less than 20 observations. The results, reported in columns (3) and (4), show similarly significant, but softer spillover effects. This evidence supports the hypothesis that internet dissemination within an industry can generate positive knowledge spillovers and network effects. On the other hand, a larger local diffusion of email across other industries significantly deteriorates manufacturing firms' performance. This also suggests that knowledge and network spillovers are more limited between firms operating in different industries, or that they are insufficient to overcome the development of internet technologies. Overall, our analysis supports the hypothesis that, at the location level, the positive intra-industry spillovers supersede the negative inter-industry ones, but also indicates that the overall or net spillover effects could be much larger if the negative inter-industry spillovers were lower. In the next sub-sections, we explore explanations for the existence of such negative inter-industry spillovers.

4.3 Threshold spillover effects

A first and obvious explanation for the existence of negative digital spillovers lies in the size of the internet user network. A critical mass of internet users might be necessary for network effects, knowledge spillovers, and other agglomeration economies to yield the expected digital dividends for SMEs (Grace et

Table 4: Inter- and intra-industry spillovers.

	(1)	(2)	(3)	(4)
Dep. Var:	Total sales	Sales per worker	Total sales	Sales per worker
	Baseline sample		Location-industry with $N_{k,l} \geq 20$	
(A) $\overline{Internet_inter}$	-16.417*** (3.323)	-14.416*** (2.508)	-7.681*** (2.012)	-6.852*** (2.716)
(B) $\overline{Internet_intra}$	23.799*** (3.313)	21.185*** (1.933)	8.362*** (1.037)	7.472*** (1.075)
	1st-stage estimates			
Endog. var (A):				
IV1	0.181*** (0.064)	0.181*** (0.064)	0.216** (0.092)	0.216** (0.092)
IV2 – Calibration: (t; t-4)	-0.0136** (0.005)	-0.0136** (0.005)	-0.017** (0.008)	-0.017** (0.008)
Weak-id SW F stat	22.18	22.18	73.33	73.33
Under-id SW Chi-2 stat.	22.68	22.68	74.95	74.95
Endog. var (B):				
IV1	0.128*** (0.032)	0.128*** (0.032)	0.206*** (0.071)	0.206*** (0.071)
IV2 – Calibration: (t; t-4)	-0.0077*** (0.0026)	-0.0077*** (0.0026)	-0.0107* (0.006)	-0.0107* (0.006)
Weak-id SW F stat	55.64	55.64	649.37	649.37
Under-id SW Chi-2 stat.	56.88	56.88	663.64	663.64
Anderson-Rubin Wald F-stat	140.99	360.73	94.81	114.62
Control variables (X_i)	Yes	Yes	Yes	Yes
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes
N	39,673	39,673	25,504	25,504

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

al., 2003). By contrast, below a certain rate of technology diffusion within industries, first movers on the new technology may capture the market share of less productive competitors or use their market power to impose barriers to new entrants. Within locations, the introduction of the technology may increase the profitability of ICT-intensive industries at the expense of less ICT-intensive industries, with possible adverse consequences for local productive capacity (Choi et al., 2020). Interestingly, Marsh et al. (2017) argue that it may take time for a technology to become widespread and fully exploited within a given industry, which points to the possibility of threshold spillover effects induced by the delayed diffusion of digital technologies within industries. This possible delay in the transmission of positive digital spillovers could also occur at the local level, within and across industries.

As a result, negative spillovers may prevail below a certain threshold of industry or location technology incidence, when the diffusion of internet technologies benefits a limited number of first-movers or dominant firms, or when firms from “old industries” are challenged by rising ICT-intensive industries; conversely positive spillovers may prevail above this threshold when email technology is ubiquitous. As such, because of the large spatial digital divide in many developing areas, it is therefore of great interest to test the existence of threshold, possibly U-shaped, spillover effects in internet technology diffusion, and to identify the threshold beyond which the positive externalities of these technologies start to prevail.

To investigate these non-linear spillover effects on manufacturing firm’s performance, we follow Wooldridge (2010, Section 9.5) and introduce into the baseline equation (1) the squared term of the internet spillover variable ($\overline{Internet}_{l(i)t(i)}^2$), yielding the following system of equations:

$$Y_i = \eta_0 + \eta_1 \cdot \overline{Internet}_{l(i)t(i)} + \eta_2 \cdot \overline{Internet}_{l(i)t(i)}^2 + \eta_3 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + v_i \quad (6a)$$

$$\overline{Internet}_{l(i)t(i)} = \beta_0 + \beta_1 \cdot Z_{l(i)t(i)} + \beta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + v_{2l(i)t(i)} \quad (6b)$$

$$\overline{Internet}_{l(i)t(i)}^2 = \theta_0 + \theta_1 \cdot Z_{l(i)t(i)} + \theta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + v_{3l(i)t(i)} \quad (6c)$$

With $(v_{1i}, v_{2l(i)t(i)}, v_{3l(i)t(i)})$ the error terms structure.

2SLS estimates of equation (6), reported in Table 5, reveal a non-linear internet spillover effect on manufacturing firms’ sales and sales per worker. After testing for the presence of a U-shaped relationship (Lind & Mehlum, 2010), we reject, within a 1% confidence-level, the hypothesis of monotone or inverse U-shaped relationship, and identify an email incidence cut-off equal to 0.535.

Second, we take the analysis in columns (3) to (6) further by replacing the location incidence simple and squared variables with their corresponding inter-industry email incidence variables in the set of endogenous regressors, controlling in parallel for the intra-industry incidence, and *vice versa*. These additional estimations support a similar U-shaped inter-industry spillover effect on manufacturing firms’ sales and sales per worker, with a close incidence cut-off value (0.45), but does not provide evidence of such a non-linearity regarding intra-industry spillovers. Hence, an insufficient email user network size appears to be a critical driver of the negative inter-industry spillovers, suggesting that an increased penetration of the internet technologies within locations and across industries would generate positive

network effects that could potentially reverse the de-industrialisation process previously observed. By contrast, intra-industry spillovers do not follow such a U-shaped curve, suggesting that knowledge and information spillovers, rather than network effects, could lie behind these within-industry externalities.

Table 5: Threshold spillovers effect.

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var:	Total sales	Sales per worker	Total sales	Sales per worker	Total sales	Sales per worker
Endogenous regressors:						
(A) <i>Internet</i>	-31.038*** (6.061)	-26.906*** (4.797)				
(B) $\overline{Internet}^2$	29.01*** (3.597)	25.581*** (2.604)				
(A) $\overline{Internet_inter}$			-26.050*** (3.479)	-23.018*** (2.712)		
(B) $\overline{Internet_inter}^2$			28.770*** (2.565)	25.690*** (1.818)		
(A) $\overline{Internet_intra}$					188.30 (207.63)	168.30 (184.79)
(B) $\overline{Internet_intra}^2$					-163.27 (196.45)	-146.01 (174.84)
Controls:						
$\overline{Internet_intra}$			0.821*** (0.310)	0.667** (0.272)		
$\overline{Internet_inter}$					-6.456 (6.807)	-5.508 (6.034)
1st-stage statistics						
Endog. var (A):						
Weak-id SW F stat	58.01	58.01	81.91	81.91	3.75	3.75
Under-id SW Chi-2 stat.	59.30	59.30	83.75	83.75	3.83	3.83
Endog. var (B):						
Weak-id SW F stat	95.38	95.38	151.31	151.31	3.50	3.50
Under-id SW Chi-2 stat.	97.50	97.50	154.70	154.70	3.58	3.58
Anderson-Rubin Wald F-stat	147.93	297.96	148.33	284.90	130.26	497.75
Control variables (X_i)	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes	Yes	Yes
N	40,154	40,154	39,673	39,673	39,673	39,673

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-year of survey.

4.4 Firms' absorptive capacity

The role of network externalities in driving Internet spillovers emphasised in the previous subsection points to the importance of manufactures' absorptive capacity, defined as a firm's "capacity to assimilate the technological knowledge created outside the firm and to apply it within its production process" (Marsh et al., p.1068). This absorptive capacity depends on various characteristics, including the skill level of the firm's workers, its maturity, its degree of export orientation, whether or not it has multi plants, and its efforts towards innovation.

In the following regressions, we start by testing whether local Internet spillovers are mediated by the firm's own use of the internet, captured by the email and website adoption dummy variables. While email adoption informs on the absorption by the firm of one of the most common, but essential, internet technologies, website adoption informs on both simple and more sophisticated uses of the internet, and in the latter case, indicates a higher capacity of the firm to absorb internet-related technological change (Sadowski, Maitland, & van Dongen, 2002; T. Harrison & Waite, 2006).

Then, we test different characteristics that are expected to reflect or contribute to a firm's absorptive capacity (Marsh et al., 2017; Vlačić, Dabić, Daim, & Vlajčić, 2019): the firm's *maturity*, proxied by its age and the experience of its top manager (in years); the firm's *worker skills*, proxied by the share of skilled workers in the production workforce and the share of non-production workers in the total workforce; the firm's degree of *export orientation*, proxied by the share of direct and indirect exports in total sales; the firm's *need for internal communications*, proxied by its multi-plant status; and the firm's *innovation efforts*, proxied by a dummy variable indicating whether the firm has introduced new processes and a dummy indicating whether the firm has invest in R&D. Each variable is introduced as an interactive term and as an additive control, if it was not already included in the baseline model, as follows:

$$Y_i = \lambda_0 + \lambda_1 \cdot \overline{Internet}_{l(i)t(i)} + \lambda_2 \cdot \overline{Internet}_{l(i)t(i)} \times ACAP_i + \lambda_3 \cdot ACAP_i + \lambda_4 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \xi_{1i} \quad (7a)$$

$$\overline{Internet}_{l(i)t(i)} = \beta_0 + \beta_1 \cdot Z_{l(i)t(i)} + \beta_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \xi_{2l(i)t(i)} \quad (7b)$$

$$\overline{Internet}_{l(i)t(i)} \times ACAP_i = \rho_0 + \rho_1 \cdot Z_{l(i)t(i)} + \rho_2 \cdot \mathbf{X}_i + d_{j(i)t(i)} + d_{l(i)} + d_{k(i)} + \xi_{3l(i)t(i)} \quad (7c)$$

Where $ACAP_i$ is the variable measuring the firm's internet technology adoption or absorptive capacity, and $(\xi_{1i}, \xi_{2l(i)t(i)}, \xi_{3l(i)t(i)})$ is the error terms structure.

First, 2SLS estimates using internet technology absorption variables – i.e. email and website adoption dummy variables – are reported in Table 6. They show that email and website adoption mediate the positive internet spillover effects on sales and sales per workers. In other words, manufacturing firms which do not use the internet face negative internet spillovers, that may result from an increased competition from other firms or failed adaptation to technological change in the structures of the local economy. The evidence in columns (1) and (3) nevertheless has to be considered with caution, since first-stage weak and under-identification tests reject the nil value of weak- or under-identification within a 5-10% confidence

level only.

Next, we analyse the firm-level characteristics that reflect a greater absorptive capacity. The results, reported in Table 7, are instructive, despite being again somewhat impaired by weak-instrument bias suspicion (except for the estimates in column (6)). They highlight that the firm’s age is a significant channel for positive internet spillovers (column (1)), and support (within a 10% confidence level) the hypothesis that newly created firms may face negative spillovers from increased local email diffusion. The results also support the idea that a firm’s multi-plant status (column (6)), which captures its internal communications requirements, is also a significant determinant of its absorptive capacity. In a less significant way but in line with existing studies (Marsh et al., 2017; Vlačić et al., 2019), the experience of the firm’s top manager (column (2)) and the share of skilled production workers in its workforce (column (3)) also contribute to its ability to benefit from internet spillovers.

Table 6: Internet spillovers and firms’ internet technology absorption.

	(1)	(2)	(3)	(4)
Dep. Var	Total sales		Sales per worker	
(A) $\overline{Internet}$	-12.728** (5.523)	-8.368*** (2.054)	-10.760** (4.511)	-6.916*** (1.749)
(B) $\overline{Internet} \times \text{email adopt}$	40.755*** (13.67)		35.937*** (10.492)	
(C) $\overline{Internet} \times \text{website adopt}$		39.323*** (3.674)		34.675*** (2.819)
	1st-stage statistics			
Endog. var (A):				
Weak-id SW F stat	3.49	8.75	3.49	8.75
Under-id SW Chi-2 stat.	3.57	8.95	3.57	8.95
Endog. var (B)/(C):				
Weak-id SW F stat	5.25	35.25	5.25	35.25
Under-id SW Chi-2 stat.	5.37	36.03	5.37	36.03
Anderson-Rubin Wald F-stat	147.93	147.93	297.96	297.96
Control variables (X_i)	Yes	Yes	Yes	Yes
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes
N	40,154	40,154	40,154	40,154
# Locations	521	521	521	521

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-year.

Table 7: Internet spillovers and firms' absorptive capacity.

Dep. Var: Total sales.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(A) $\overline{Internet}$	-5.852* (3.079)	-6.186 (3.980)	-46.96* (24.55)	-77.86 (362.07)	147.88 (1224.7)	1.009 (1.278)	7.223 (5.552)	5.206 (10.21)
(B) $\overline{Internet} \times ACAP$:								
Age (years)	0.660*** (0.242)							
Experience (years)		0.566* (0.327)						
Skilled prod. work. (%)			81.57* (44.10)					
Non-prod. work. (%)				282.03 (1326)				
Dir. and indir. exports (%)					-37.71 (320.1)			
Multi-plant firm (0/1)						37.57*** (4.406)		
Innovation (0/1)							-3.819 (4.931)	
RD spending (0/1)								43.52 (79.67)
ACAP additive var.	-0.531*** (0.167)	-0.402** (0.186)	-58.60* (32.70)	-195.46 (947.76)	30.594 (259.02)	-29.47*** (3.050)	3.488 (4.200)	-37.33 (68.88)
	1st-stage statistics							
Endogenous var. (A):								
Weak-id SW F stat	5.71	6.25	4.08	0.18	0.01	73.57	8.38	1.58
Under-id SW Chi-2 stat.	5.86	6.42	4.19	0.19	0.01	75.54	8.64	1.63
Endogenous var. (B):								
Weak-id SW F stat	7.89	3.74	4.05	0.15	0.01	73.80	8.59	0.48
Under-id SW Chi-2 stat.	8.10	3.84	4.15	0.16	0.01	75.77	8.86	0.49
Anderson-Rubin Wald F-stat	69.99	69.99	64.14	64.14	64.14	62.14	1.17	1.41
Control variables (X_i)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	31,407	31,407	31,407	31,407	31,407	31,313	23,043	23,075

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

5 Robustness checks

In a last step, we conduct robustness checks which consist in applying various restrictions to our estimation sample to address possible sample selection bias. First, even though concern over endogeneity is limited when bias suspicion applies to the aggregate shock's weighting factors (Borusyak et al., 2018), we adopt a conservative approach and ensure that our estimates are not affected by spatial inequalities, induced by the highest performing firms choosing to locate in urban centres or close to the coast where most connectivity and maritime infrastructures are deployed. To address this source of endogeneity, we first exclude large and multi-plant firms from the sample, but also foreign firms (i.e. those that are more than 50% foreign owned) and exporting firms (i.e. those for which the share of direct or indirect exports in total sales is above 0), which are more likely to be mobile when choosing their location (Dollar et al., 2005; Dollar, Hallward-Driemeier, & Mengistae, 2006). We then rerun IV-2SLS estimations of equations (1),(5), and (6) on this restricted sample. The results in Table 8 show that, despite the sample attrition, our findings remain robust to this check.

As a second robustness check, we make sure that the estimated relationships are not affected by a low number of firms in some locations, by imposing a minimum of 50 firms in the locations to be considered in estimations. In fact, locations that are far from infrastructures may host a smaller number of firms, among which less performing firms may be over-represented. Our estimates, reported in Table 9, are robust to this additional restriction.

Finally, we exclude landlocked countries from the sample because they cannot host SMCs, and can only be indirectly connected to them via the terrestrial cable network. Although the presence of fixed-effects controls for the consequences of this geographical feature on telecommunication outcomes, landlocked countries are particularly dependent on cross-border connectivity with neighbouring coastal countries hosting SMCs. Non-treatment of this could therefore have heterogeneous impacts for these countries because of unobserved information on deployment of the terrestrial infrastructure network and on cross-border connectivity. This restriction leads us to exclude 29 countries, corresponding to 5,444 manufacturing firms. The results, reported in Table 10, confirm our previous estimations.

6 Conclusion

Internet technologies play a critical role in environments where firms are strongly constrained in their daily interactions by large transactions costs, missing infrastructures and high levels of uncertainty. The adoption and diffusion of new technologies are likely to deliver net benefits, but these may not always be guaranteed due to conflicting spillover effects.

Focusing on manufacturing firms in a large sample of developing and transition economies, this paper shows that beyond the direct benefits of internet adoption by manufacturers, local diffusion of internet technologies within and across industries has yielded strong and positive spatial spillover effects on manufacturing firms' revenues and productivity. In fact, SSIV estimations document a positive effect of an

Table 8: Internet spillovers for inward-oriented SMEs.

	(1)	(2)	(3)	(4)	(5)	(6)	
Dep. Var		Total sales		Sales per worker			
(A) $\overline{Internet}$	1.061** (0.548)		-15.760*** (1.687)	1.358** (0.585)		-11.930*** (1.865)	
(B) $\overline{Internet_inter}$		-7.727*** (0.885)			-5.949*** (1.159)		
(C) $\overline{Internet_intra}$		10.01*** (0.787)			8.087*** (0.933)		
(D) $\overline{Internet}^2$			15.627*** (1.102)			12.345*** (1.478)	
			1st-stage statistics				
Endog var: (A)							
Weak-id SW F stat	123.97		131.19	123.97		112.27	
Under-id SW Chi-2 stat.	256.63		135.79	256.63		115.93	
Endog var: (B)							
Weak-id SW F stat		71.35			71.35		
Under-id SW Chi-2 stat.		73.86			73.86		
Endog var: (C)							
Weak-id SW F stat		174.14			174.14		
Under-id SW Chi-2 stat.		180.27			180.27		
Endog var: (D)							
Weak-id SW F stat			239.21			239.21	
Under-id SW Chi-2 stat.			247.60			247.60	
Anderson-Rubin Wald F-stat	73.01	68.18	73.01	29.61	28.55	29.61	
Hansen test p-val.	0.23	-	-	0.26	-	-	
Control variables (X_i)	Yes	Yes	Yes	Yes	Yes	Yes	
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes	Yes	Yes	
N	22,040	21,761	24,427	22,040	21,761	24,427	

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

Table 9: Internet spillovers in locations with $N \geq 50$ observations.

	(1)	(2)	(3)	(4)	(5)	(6)	
Dep. Var		Total sales			Sales per worker		
(A) $\overline{Internet}$	3.466*** (0.508)		-15.216*** (1.797)	3.694*** (0.514)		-11.432*** (2.105)	
(B) $\overline{Internet.inter}$		-16.298*** (3.485)			-14.934*** (2.878)		
(C) $\overline{Internet.intra}$		21.947*** (2.447)			20.371*** (1.648)		
(D) $\overline{Internet}^2$			14.899*** (1.199)			11.692*** (1.579)	
			1st-stage statistics				
Endog var: (A)							
Weak-id SW F stat	115.44		57.55	115.44		57.55	
Under-id SW Chi-2 stat.	235.57		58.72	235.57		58.72	
Endog var: (B)							
Weak-id SW F stat		29.21			29.21		
Under-id SW Chi-2 stat.		29.81			29.81		
Endog var: (C)							
Weak-id SW F stat		73.65			73.65		
Under-id SW Chi-2 stat.		75.15			75.15		
Endog var: (D)							
Weak-id SW F stat			101.10			101.10	
Under-id SW Chi-2 stat.			103.15			103.15	
Anderson-Rubin Wald F-stat	270.75	247.11	68.35	420.94	441.06	50.59	
Hansen test p-val.	0.20	-	-	0.21	-	-	
Control variables (X_{it})	Yes	Yes	Yes	Yes	Yes	Yes	
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes	Yes	Yes	
N	38,622	38,326	38,622	38,622	38,326	38,622	

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

Table 10: Internet spillovers, excluding landlocked countries.

	(1)	(2)	(3)	(4)	(5)	(6)	
Dep. Var		Total sales			Sales per worker		
(A) $\overline{Internet}$	2.953*** (0.508)		-30.376*** (5.739)	3.500*** (0.524)		-25.083*** (3.877)	
(B) $\overline{Internet.inter}$		-15.824*** (3.1047)			-13.073*** (2.009)		
(C) $\overline{Internet.intra}$		23.236*** (3.132)			20.286*** (1.768)		
(D) $\overline{Internet}^2$			28.701*** (3.413)			24.615*** (2.086)	
			1st-stage statistics				
Endog var: (A)							
Weak-id SW F stat	137.63		56.58	137.63		56.58	
Under-id SW Chi-2 stat.	281.83		57.94	281.83		57.94	
Endog var: (B)							
Weak-id SW F stat		18.67			18.67		
Under-id SW Chi-2 stat.		19.12			19.12		
Endog var: (C)							
Weak-id SW F stat		48.44			48.44		
Under-id SW Chi-2 stat.		49.61			49.61		
Endog var: (D)							
Weak-id SW F stat			94.55			94.55	
Under-id SW Chi-2 stat.			96.81			96.81	
Anderson-Rubin Wald F-stat	124.98	123.81	124.98	413.53	451.27	413.53	
Hansen test p-val.	0.19	-	-	0.21	-	-	
Control variables (X_i)	Yes	Yes	Yes	Yes	Yes	Yes	
Fixed effects (d_{jt}, d_l, d_k)	Yes	Yes	Yes	Yes	Yes	Yes	
N	34,662	34,344	34,662	34,662	38,326	34,662	

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

increased incidence of email use within a region/city on manufactures' performance. The effect on sales and sales per worker is of equal size, suggesting that such Internet spillovers are neutral in terms of employment level. However, these spillovers are subject to important threshold effects: the network of email users has to reach a critical size in order for the positive externalities of internet diffusion to be effective. Otherwise, our findings show that the burgeoning diffusion of internet technologies may only benefits first-movers and large and productive firms with sufficient absorptive capacity, at the expense of more fragile ecosystems, thereby concomitantly causing manufacturing output to decline. We indeed find evidence of negative spatial spillover effects on manufacturing firms' sales and productivity from internet diffusion across industries on manufactures' sales and productivity, where email incidence is below a threshold corresponding approximately to 50%. At the firm level, we also show that the sign of these spillover effects critically hinges on manufactures' absorptive capacity. These results therefore lend credibility to the hypothesis that email diffusion may, in certain contexts, primarily benefit the highest performing firms, as already evidenced in other studies (Bustos, 2011; Paunov & Rollo, 2016; Rodrik, 2018).

Our empirical analysis, in line with recent findings on digitalisation in developing countries (Hjort & Poulsen, 2019; Cariolle et al, 2019; IMF, 2020), supports the idea that net internet spillovers on the manufacturing sector are strong and positive. But these positive spillovers could be even greater if the spatial digital divide were reduced and the manufacturing sector's absorptive capacity reinforced.

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Appendix

Appendix A. Sample statistics

A.1. Sample statistics, by fiscal year.

Fiscal year	Freq.	Percent	Fiscal year	Freq.	Percent
2005	5,447	13.57	2012	9,823	24.46
2006	2,871	7.15	2013	3,261	8.12
2007	3,208	7.99	2014	508	1.27
2008	1,749	4.36	2015	949	2.36
2009	4,480	11.16	2016	1,892	4.71
2010	1,609	4.01	2017	56	0.14
2011	4,301	10.71	Total	40,154	100

A.2. Sample statistics, by industries (WBES stratification sectors).

Sector	Freq.	Percent	Sector	Freq.	Percent
Agriculture	3	0.01	Manuf. other non-metallic min..	2,670	6.65
Chemicals Chemical Prod.	3,411	8.49	Manuf. other transport equipm.	107	0.27
Construction	3	0.01	Manuf. paper prod.	513	1.28
Hotels restaurants	1	0.00	Manuf. petroleum prod.	89	0.22
Manuf. basic metals	1,159	2.89	Manuf. rubber & plastics	2,494	6.21
Manuf. electrical machinery	1,323	3.29	Manuf. textiles	2,708	6.74
Manuf. electronic equipment	229	0.57	Manuf. tobacco prod.	161	0.40
Manuf. fabricated metal prod.	3,349	8.34	Manuf. wearing apparel	5,043	12.56
Manuf. food prod.	7,999	19.92	Manuf. wood prod.	1,120	2.79
Manuf. furniture	2,048	5.10	Mining	2	0.00
Manuf. leather prod.	824	2.05	Other Manuf.	65	0.16
Manuf. machinery & equipment	2,342	5.83	Other business activities	2	0.00
Manuf. medical instruments	211	0.53	Publishing and printing	1,320	3.29
Manuf. motor vehicles	852	2.12	Recycling	91	0.23
Manuf. office	15	0.04	Total	40,154	100

A.3. Sample statistics, by country.

iso	Email incidence	Std. Dev.	Freq.	iso	Email incidence	Std. Dev.	Freq.	iso	Email incidence	Std. Dev.	Freq.
AFG	0.44	0.50	144	GTM	0.81	0.39	619	NGA	0.22	0.42	539
AGO	0.21	0.41	305	HND	0.67	0.47	395	NIC	0.53	0.50	495
ALB	0.71	0.46	136	HRV	0.91	0.29	371	NPL	0.57	0.50	355
ARG	0.98	0.15	1509	IDN	0.39	0.49	1821	PAK	0.44	0.50	437
ARM	0.70	0.46	107	IND	0.87	0.34	6241	PER	0.94	0.24	1343
AZE	0.41	0.49	121	IRQ	0.19	0.39	464	PHL	0.84	0.37	1231
BDI	0.47	0.50	154	JAM	0.88	0.33	57	PNG	0.95	0.21	22
BEN	0.70	0.46	50	JOR	0.73	0.45	197	PRY	0.82	0.38	417
BFA	0.74	0.44	70	KAZ	0.82	0.39	249	RUS	0.96	0.21	1227
BGD	0.45	0.50	1062	KEN	0.87	0.34	251	RWA	0.44	0.50	55
BGR	0.88	0.32	678	KGZ	0.62	0.49	152	SEN	0.38	0.49	414
BIH	0.93	0.26	177	KHM	0.52	0.50	95	SLE	0.23	0.42	74
BLR	0.85	0.36	142	LAO	0.23	0.42	53	SRB	0.95	0.22	155
BOL	0.85	0.36	420	LBN	0.80	0.40	159	SSD	0.32	0.47	79
BRA	0.95	0.21	781	LBR	0.30	0.46	69	SWZ	0.73	0.45	114
BWA	0.48	0.51	33	LKA	0.35	0.48	295	TCD	0.23	0.43	56
CHN	0.90	0.30	1454	LSO	0.67	0.47	64	THA	0.76	0.43	486
CIV	0.39	0.49	198	MAR	0.95	0.22	80	TJK	0.48	0.50	153
CMR	0.61	0.49	142	MDA	0.71	0.45	119	TTO	0.90	0.30	101
COD	0.27	0.45	443	MEX	0.77	0.42	1791	TUN	0.97	0.18	264
COL	0.94	0.24	1552	MKD	0.85	0.36	187	TUR	0.91	0.28	106
CRI	0.96	0.19	223	MLI	0.30	0.46	427	TZA	0.40	0.49	257
DJI	0.77	0.43	22	MMR	0.30	0.46	620	UGA	0.34	0.47	494
DOM	0.91	0.29	90	MNE	0.75	0.44	48	UKR	0.77	0.42	697
ECU	0.96	0.21	451	MNG	0.55	0.50	100	URY	0.84	0.37	464
ETH	0.64	0.48	417	MOZ	0.22	0.42	340	VEN	0.93	0.25	60
GEO	0.61	0.49	147	MRT	0.60	0.49	110	YEM	0.29	0.45	237
GHA	0.41	0.49	540	MWI	0.25	0.46	8	ZAF	0.79	0.41	524
GIN	0.22	0.41	139	MYS	0.77	0.42	452	ZMB	0.58	0.49	553
GMB	0.30	0.47	33	NAM	0.76	0.43	152				
GNB	0.47	0.50	45	NER	0.45	0.51	20	Total	0.72	0.45	40154

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