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Bilateral digital connectivity and firm participation in export markets*

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Abstract

This paper studies how bilateral digital connectivity resulting from telecommunications submarine cable (SMC) deployment affects firm participation in export markets. Using an unbalanced panel of bilateral trade data from 48 countries during the period 1997-2014, we find that a SMC connection between two countries is associated with an increase in the number of bilateral exporters in developed countries, but also with a reduction in the number of bilateral exporters in developing countries. This negative association between bilateral connectivity and firm participation in export markets appears to be stronger in the poorest developing areas: Middle East and North Africa, South Asia and Sub-Saharan Africa. The growth in world connectivity spurred by SMCs deployment has therefore had a heterogeneous effect on firm decision to export, pushing more firms from high-income countries to enter export markets, and some incumbent exporters from lower-income countries to exit them.

Keywords: Internet Connectivity, ICT, Submarine cables, Export behaviour
JEL classification: F14, O33, O19.

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1 Introduction

ICTs are network goods with a proven cost-reduction potential (Björkegren, 2019; Goldfarb & Tucker, 2019), which gets stronger as the size and capacity of the worldwide telecommunication network increase (Katz & Shapiro, 1985; Crémer, Rey, & Tirole, 2000). In this regard, the fibre-optic Submarine Cable (SMC) network, the world digital connectivity cornerstone, has considerably densified during the last two decades, facilitating Internet communications and spurring the growth of related digital technologies. Today, almost all coastal countries, including lower-income countries, use this infrastructure to get access to broadband Internet (Hjort & Poulsen, 2019; Cariolle, 2020). As a result, broadband Internet has plausibly prompted the 'death of distance' between trade partners and thereby fostered countries' and firms' participation in international trade of goods and services, by reducing information-search and communication costs between buyers and sellers worldwide (Freund & Weinhold, 2002, 2004; Clarke & Wallsten, 2006; Lendle, Olarreaga, Schropp, & Vézina, 2016).

To date, there is little international evidence on the impact of telecommunication infrastructure deployment on international trade patterns, especially in developing countries (Hjort & Poulsen, 2019). Evidence at the bilateral level is particularly lacking. This paper contributes to fill this gap by exploring how extended bilateral connectivity, permitted by the laying of SMCs between countries, affects the country's bilateral export performance, with a focus on the extensive margin of firms, i.e. the number of firms involved in export activities. The analysis is conducted using unbalanced panel data, drawn from the World Bank's Exporters Dynamics Database (EDD) (Fernandes, Freund, & Pierola, 2016), on the number of bilateral exporters in 48 coastal countries during the period 1997-2014, and the bilateral data on the maritime telecommunications infrastructure deployment from Telegeography database. In particular, we study how a SMC connection between two countries affects firm's bilateral export participation, by differentiating the effects between developed and developing countries.

We provide evidence that subsequent to an increase in bilateral SMC connections, the number of exporting firms increases in developed countries and declines in developing countries, especially in Middle East and North Africa (MENA), South Asia (SA) and Sub- Saharan Africa (SSA). Inspired by the literature on trade in a heterogeneous firm setting (e.g. Melitz, 2003; Bustos, 2011; Fernandes et al, 2016; Dickstein & Morales, 2018) , we interpret this finding as evidence that firms from developed and developing areas differ in their ability to undertake information technology upgrading. In fact, most firms in developed countries can benefit from broadband Internet and related information technologies, thanks to a greater absorptive capacity (in terms of digital skills, R& D investment, and organisational structure) and greater proximity to urban centres and hard infrastructures (Galliano & Roux, 2008; Marsh, Rincon-Aznar, Vecchi, & Venturini, 2017). Conversely, in developing countries, the number of exporting firms can decline following an improved bilateral digital connection as only the largest and the high-productivity firms tap into the Internet. The remaining firms might consist of non-exporters, and small and low-productivity exporters, which are unable to fully exploit Internet potential.

It is worth noting that our results are unlikely to be affected by omitted variable bias, as the panel structure of our dataset enables the inclusion of country-year and export destination-year fixed effects, and thereby, to control for unobserved time-varying factors for each country or destination that could drive both export performance and SMC deployment. Time-invariant export origin-destination country fixed effects are also included to control for geographical or long-lasting historical characteristics, such as past colonial history, that could also explain the bilateral trade or SMC rollout between two countries. As result, the endogeneity problem is very unlikely to be a serious concern in our econometric specification. Nevertheless, we implement an exogeneity test, which confirms that causality runs from bilateral SMC connection to the number of exporting firms at the bilateral level.

Previous studies have already highlighted a positive effect of Internet adoption on exports at the bilateral level (Freund & Weinhold, 2004; Osnago & Tan, 2016; Visser, 2019), but to our knowledge there is no evidence on firm bilateral export decisions. A positive relationship between Internet access and trade has also been evidence in cross-section and panel data analyses, especially when it deals with service exports (Freund & Weinhold, 2002; Choi, 2010), with differentiated export goods (Tang, 2006), or with exports from developing countries destined to developed countries (Clarke & Wallsten, 2006). Other studies analyse how firm's Internet use affects firm's export performance, using repeated cross-section firm-level data from small samples in selected countries. For example, using data from Eastern-European and Central-Asian countries, Clarke (2008) found a positive effect of internet access on firm's probability to export but no significant effect on exports share in total sales; whereas, using firm-level data from six African countries, Hjort and Poulsen (2019) showed that the arrival of SMC positively affected firm exports at the expense of domestic sales. Recent papers also analyse the internet-trade nexus using firm-level panel data, but from a single country's perspective, without giving a cross-country perspective. For instance, using data from United Kingdom, Kneller and Timmis (2016) found a positive association between use of broadband Internet and export propensity for business services firms, while Fernandes, Mattoo, Nguyen, and Schiffbauer (2019) found that increased Internet penetration at the province level positively affected Chinese firms' inclination and intensity to export.

Our study provide a novel evidence on the ICT-trade nexus, while combining various features of previous studies. To our knowledge, this paper is the first to emphasize the contribution of the SMC network – the first stage in the Internet access value chain (Schumann & Kende, 2013) – to the extensive margin of exports, using bilateral data in a large sample of developed and developing countries, to explore how international digital connectivity affects firm's participation in export markets.

The rest of the paper is organized as follows. Section 2 gives a short review of the literature on the effect of ICT adoption, especially Internet technology, on trade performance. Section 3 describes the background of our study. Section 4 details our empirical strategy, while section 5 reports our empirical results. Section 6 concludes.

2 Literature review

The following section exposes a non-exhaustive but representative review of the literature on the ICT-trade nexus. This literature generally points to a positive effect of ICT adoption and diffusion on macro and micro-level measures of trade performance, especially for trade in services.

In the 2000s, in parallel to the emergence of the digital economy, the literature examining the effect of Internet on international trade has grown. In one of the first papers providing international evidence on this relationship, Freund and Weinhold (2004) introduced in a traditional gravity model a variable approximating the diffusion of Internet by the number of web hosts with export origin country's domain name in export destination country, and *vice versa*. Their results, based on a sample of 56 countries, show that Internet bilateral expansion encouraged trade over the 1997-1999 period, especially in developing countries. To overcome a possible reverse causality bias from trade creation to Internet diffusion, the authors lagged their web host variable.

Following this pioneer empirical work, cross-country analyses of the effect of ICT adoption on bilateral trade have been relatively scarce, regaining attention from researchers at the end of the 2010s. Among these studies, those conducted by Osnago and Tan (2016) and by Visser (2019) are of particular interest because they provide international evidence on the Internet effects on bilateral trade margins. Osnago and Tan (2016) assess the impact of Internet access on bilateral exports, differentiating the effect of Internet penetration in exporting and importing countries, using a panel dataset of aggregated trade flow from 2001 to 2013. To address the reverse causality bias between bilateral trade flows and Internet adoption in partner countries, they adopt an instrumental variable (IV) approach consisting in instrumenting Internet penetration rates in exporting and importing countries by broadband subscription tariffs. Their findings highlight a positive effect of Internet adoption in exporting countries on bilateral exports, mostly driven by the extensive margin of trade, i.e. a greater number of exported products, and by trade in differentiated products (as defined by Rauch (1999)). However, the effect of Internet adoption in importing countries on total bilateral exports remains indeterminate, since a positive and significant effect of Internet on the intensive margin of trade, as measured by the average value of bilateral exports, is found to be offset by a negative effect on the extensive margins of trade. Visser (2019) conducts a similar analysis using a gravity model based on panel bilateral trade data from 162 origin countries to 175 destination countries, for the period 1998-2014. The author's findings support the positive effect of Internet adoption on differentiated products bilateral trade. He also stresses that a greater Internet penetration in developing countries increases exports to high-income countries along both the extensive and intensive margins, while increasing exports to lower-income countries along the intensive margin only.

Other studies have furthered the comprehension of the effect of Internet on trade in developed and developing economies through aggregate cross-country or panel data analyses. Clarke and Wallsten (2006) estimate the effect of Internet adoption on total exports, exports to high-income countries and exports to low-income countries, for a sample of 98 developed and developing countries. Using data on the stringency of monopoly regulation in the telecommunications market as an IV, they find evidence of a positive effect of

Internet penetration (Internet hosts per 100 individuals or the share of Internet users in the population) on trade, only in the case of exports from developing countries to developed countries. Their results indicate that a 1% increase in Internet hosts raises exports from developing countries to developed countries by 0.4%. Focusing on service trade in 151 countries between 1990 and 2006, Choi (2010) finds that a 10% increase in the share of Internet users in the population raises service trade by 0.23%, with service exports more stimulated than service imports. These results hold when the author controls for the endogeneity of the Internet variable by using the GMM estimator. These findings confirm previous evidence brought by Freund and Weinhold (2002) on the positive contribution of Internet diffusion to the growth in services trade in the US.

In the wake of Freund and Weinhold (2002), recent analyses have narrowed their scope on a single country to investigate the impact of broadband adoption on trade, especially firm's export performance. Tang (2006) stresses how communication costs reduction over 1975-2000, permitted by the first fibre optic cables rollout in the 90s, has had a positive impact on US imports of differentiated products and referenced-price goods. Kneller and Timmis (2016) follow an instrumental variable (IV) approach based on telephone network historical data and put in evidence a positive effect of broadband use on the firm-extensive margin of UK service exports. Fernandes et al. (2019) found that increasing the number of Internet users per-capita at the province level in China boosted Chinese manufactures' likelihood to export and export intensity. They stress that this effect is stronger when firms operate in industries using Internet more intensively. More close to our study, Akerman, Leuven, and Mogstad (2021) exploit the staggered roll-out of local fiber-optic broadband access-points in Norway to estimate the causal effect of Internet adoption on Norwegian firms' bilateral exports. They find that the reduction in information friction induced by Internet access enlarges the choice set of exporters and importers, making demand for traded products more elastic to trade costs and to distance.

This paper differs from these studies in that it is the first study, to our knowledge, exploiting data on the bilateral SMC infrastructure to estimate the impact of improved digital connectivity between countries on their bilateral trade. SMC rollout coincides with the development of cheaper and faster telecommunications (Tang, 2006; Weller & Woodcock, 2013; Hjort & Poulsen, 2019), including broadband Internet, spurring the digitisation of information and communication contents and the digitalisation of economic interactions.[1] Ultimately, SMC rollout has permitted the rise and development of two-sided markets, "in which an intermediary (Visa, Sony, Alphabet, Facebook, the real estate agency) enables sellers and buyers to interact" at low cost (Tirole, 2017, p.379). Two-sided markets bring together the supply and demand for different products and services through different types of digital platforms.[2] For digital goods, the emergence of digital platform announced the death of geographical distance, while for physical goods they permitted significant transaction-cost reduction (Goldfarb & Tucker, 2019; Akerman et al., 2021). Our contribution here is the focus on the role played by bilateral SMC connections, the

[1]Digitisation refers to the "representation of information in bits [...] rather than atoms" (Goldfard & Tucker, 2019, p.3). Digitalization refers to the increase use of digital technologies in the conduct of business and in daily life human interactions.

[2]With the most significant successes being Amazon in industrialized countries, Alibaba in China, or Jumia in West Africa. For an overview of two-sided markets development in sub-Saharan Africa, see Cariolle and Carroll (2020).

backbone architecture of the world telecommunications network, as a structural determinant of digitization and digitalization of international exchanges – and thereby, as a catalyst of international trade flows.

Second, the paper analyses bilateral trade from the perspective of firms' participation in export markets, as reflected by a country's total number of firms serving a specific export market at a given point of time. From this perspective, this is also an important contribution since most studies addressing firm's ICT adoption and export decisions focus on a single country (Visser, 2019). We therefore complete the picture of worldwide trade dynamics given by Fernandes et al. (2016), by emphasizing the critical role of international digital connectivity in bilateral exports dynamics, using an unbalanced panel of 48 coastal countries over 1997-2014. Last, our empirical strategy also stands out by exploiting the panel structure of the data that account for the universe of exporting firms from several countries in the world of heterogeneous income levels. This panel structure also allows controlling for a wide range of unobserved characteristics, by including a large set of fixed effects, thereby strongly lowering the concern for omitted variable bias.

Overall, our findings tend to temper previous evidence on the positive effect of Internet diffusion on trade, since we identify heterogeneous effects of bilateral connectivity on trade participation, depending firm's home country income-group and geographical location.

3 Background and motivation

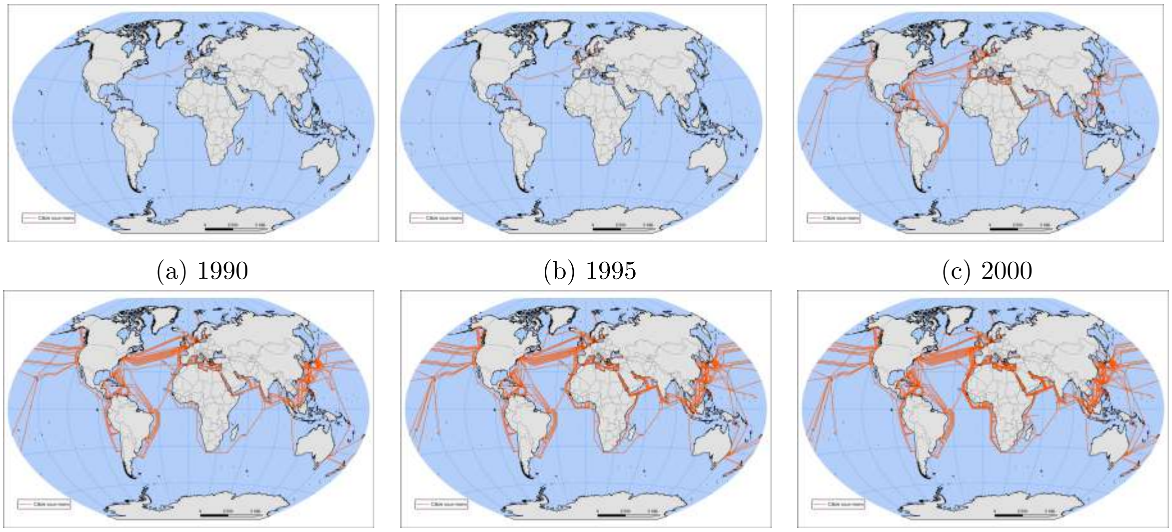
3.1 Submarine cables rollout and the digital interconnection process

Over the last few decades, digital connectivity, defined as the capacity to exchange digitised information, has been boosted by the laying of some 400 fibre-optic submarine cables (SMCs) worldwide (Cariolle, Le Goff, & Santoni, 2019). Nowadays, more than 99% of the world's telecommunications – Internet content, phone and video calls, classified diplomatic messages – passes through SMCs. By connecting a country to the international telecommunication network, the deployment of SMCs is a technological push towards the digitisation and digitalisation of economies.

Since the first deployment of the TAT-8 transatlantic fibre-optic cable in 1988, connecting the US to Great-Britain and France, the world SMC network has undergone a dramatic densification, together with a considerable increase in the capacity and velocity of transmitting information. Figure 1 shows that Northern industrialized countries have been the first recipients of these cables, followed by Latin America, the Middle-East and Asia in the early in the wake of the 2000 Internet bubble. Africa started to benefit from the international maritime infrastructure with the arrival of high-capacity SMCs after 2005 (Cariolle, 2020).

The SMC network is the central infrastructure of the worldwide telecommunications network, and the first element of the Internet access value-chain presented in Figure 2. Without SMC, a country has two costly and less efficient alternatives to be internationally connected: i) buying Internet bandwidth in a SMC-connected neighboring country, or ii) resorting to expensive communication satellites. A greater

Figure 1: SMC worldwide deployment over time



(a) 1990 (b) 1995 (c) 2000

(d) 2005 (e) 2010 (f) 2015

Source: Authors' elaboration using data from the Telegeography database: https://www.submarinecablemap.com/

number of SMCs is therefore expected to boost the digital economy by increasing Internet speed and the total bandwidth available to international communications. More bandwidth reduces the cost of increasing the penetration of Internet and other ICTs, increases the quality of related services, the competition environment in the telecommunications (and other) sector(s), and the resilience of the telecommunications network (in case of cable faults) (Cariolle, 2018, 2020; Cariolle et al., 2019).

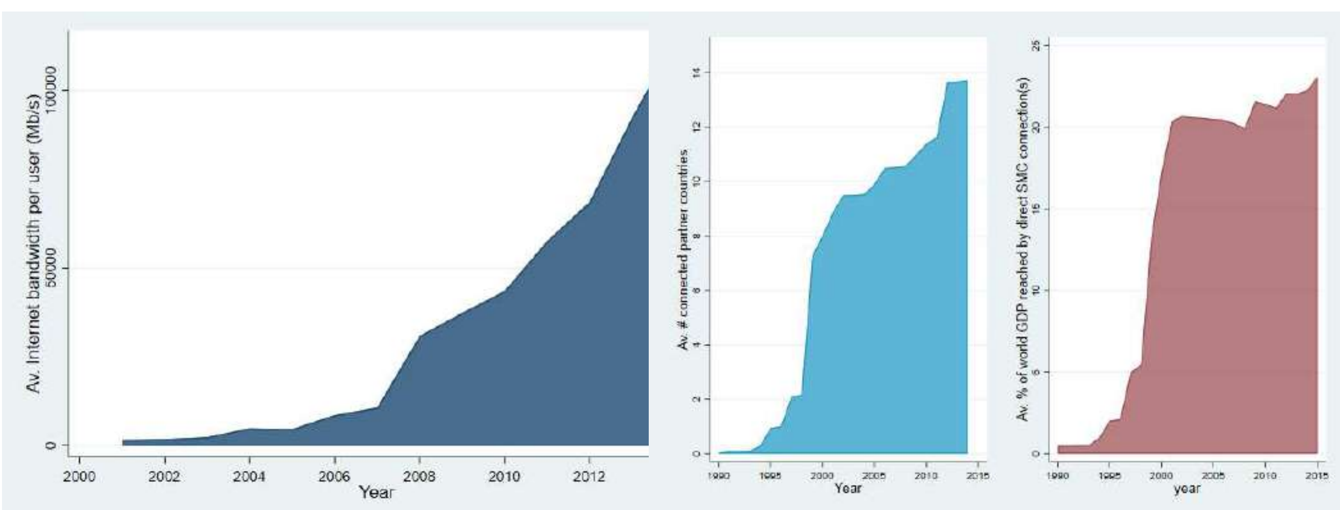
Therefore, the deployment of SMCs increased the worldwide telecommunications network size, capacity and redundancy.[3] From the years 2010 onward, the SMC infrastructure was bringing together more than 3 billion Internet users, building digital bridges between almost all coastal countries, and irrigating a multi-trillion dollar industry (Nyirenda-Jere & Biru, 2015). To illustrate the magnitude of this technological push induced by SMC deployment, in 2013, "twenty households with average broadband usage generate as much traffic as the entire Internet carried in 1995" (Weller & Woodcock, 2013). This exponential improvement in digital connectivity is reflected in Figure 3, plotting the evolution of three connectivity indicators: (i) the available global bandwidth per user; (ii) the average number of partner countries connected by cables, and; (iii) the country average share of world GDP reached by direct SMC bilateral connections. According to these number, in 2015, a country was on average directly connected by cables to almost 14 countries, representing close to one quarter of the world GDP, and was benefiting from an average international bandwidth of 100,000 Mbit/s per user. The sharp rise in these metrics give a striking idea of the dramatic increase in connectivity induced by the laying of SMCs.

[3]The redundancy is the ability to maintain a capacity for telecommunications when a shock affects the infrastructure, by re-rooting telecommunications traffic towards alternative paths.

Figure 2: Internet access value chain and key telecommunication infrastructures.

Source: Cariolle (2020), adapted from Schumann and Kende (2013).

Figure 3: SMCs rollout and the world connectivity.



Source: ITU database, https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx, Telegeography database: https://www.submarinecablemap.com/ and World Development Indicators https://databank.worldbank.org/source/world-development-indicators.

3.2 Bilateral connectivity, Internet access, and firm trade

The massive worldwide deployment of broadband SMCs has been a major driver of progress for the Internet economy's expansion, including new forms of trade such as e-commerce. In particular, the deployment of SMCs between countries could have accelerate bilateral trade, by improving firm access to information on foreign markets, communication with trade partners, and thereby, spurring their participation in export markets.

SMC rollout between two countries is expected to boost bilateral trade flows through lowered transaction costs and information costs (Freund & Weinhold, 2002, 2004; Clarke & Wallsten, 2006; Dickstein & Morales, 2018; Dasgupta & Mondria, 2018). Bilateral SMC rollout is indeed expected to fluidize telecommunications between recipient countries, by reducing the rerouteing of telecommunications traffic towards indirect cable paths, thereby increasing the speed and available bandwidth for bilateral telecommunications, and limiting operators exposure to rerouteing costs charged by owners of indirect cable connections. As a result, following the predictions of the ubiquitous gravity model, bilateral trade should be intensified at the extensive and intensive margins thanks to the reduction in bilateral trade and information costs (Dickstein & Morales, 2018).

A growing body of evidence reveals that the reduction in trade costs and technological upgrading have important implications for international trade patterns. The question of whether and how improved bilateral connectivity affects firms' bilateral export participation is motivated by the theoretical models on firm heterogeneity and international trade developed by Melitz (2003), and Bustos (2011). SMCs arrival may indeed strongly reduce trade costs incurred by firms, since the network effects of Internet use – in particular the reduction in information search and communication cost induced by network densification – increase with the number of bilateral cable connections. However, these benefits are unequally distributed among firms, since only the biggest or the most productive ones will be able to incur the fixed costs associated with Internet access, and to undertake organizational changes required to fully exploit the potentialities of Internet connectivity.

In fact, the standard heterogeneous firm model of trade proposed by Melitz (2003) highlights that only the most productive firms export since they are able to cover the additional export costs, while the remaining firms only supply the domestic market. Thus, following a reduction in bilateral trade costs, more firms start supplying foreign markets, while the least productive firms exit the market due to market shares losses. Likewise, by reducing trade and information costs, the arrival of SMCs linking the two countries should increase the number of firms exporting to these respective markets. This is, however, conditional on the ease of access to Internet technologies by the majority of firms and to complementary inputs necessitated for exporting (e.g. hard infrastructure like roads).

In this regard, Bustos (2011) shows that in developing countries, like Argentina, only high-productivity exporting firms are able to upgrade their technology, whereas both low-productivity exporters and non-exporters cannot, since the fixed costs of technology upgrading might be larger than the fixed costs of exporting. Therefore, a reduction in costs of Internet access may lead a greater number of exporters to adopt Internet, while pushing the least productive exporters to exit foreign markets and the least productive non-exporters to entirely stop their business, due to market share losses.

Echoing Bustos' findings on the heterogeneous effect of technology upgrading on firm's participation in export markets, Dickstein and Morales (2018) examine the effect of the information possessed by exporters on their decision of serving a specific export market. They find that larger firms are better informed on foreign market conditions compared to smaller ones, and that the formers' export profits increase with improved access to information, while the latter's profit remain unchanged. Overall, they show that better information on export markets increases total export revenues and profits, while reducing the range of export destination markets. Importantly, this increase in export proceeds mostly accrue to large firms, which benefit from a productivity advantage over small firms and informational advantage in foreign markets.

Therefore, following a reduction in bilateral information and communication costs permitted by the arrival of SMCs linking two countries, these recent contributions suggest that the number of exporting firms should increase in developed countries, where firms are more productive, larger, better informed and more likely to absorb digital technology. By contrast, this number is expected to decline in developing countries, since only the largest and most productive exporting firms might be able to benefit from Internet access. It is interesting to note that Foster et al (2018) report results from 264 interviews in 3 export sectors (tea, tourism, business process outsourcing) in Kenya and Rwanda that comfort these findings. They document that small producers are only thinly digitally integrated in global value chains (GVCs). They conclude that improving connectivity does not benefit African firms in GVCs unless supported by complementary capacity. Thus, this brings us to test the following hypothesis:

> ***Testable hypothesis****: Subsequent to the arrival of SMCs at the bilateral level, the number of exporting firms increases in developed countries and declines in developing countries.*

4 Empirical strategy

4.1 Data

We use bilateral trade data from the World Bank's Exporter Dynamics Database (EDD), which contains aggregated measures on export characteristics from 68 countries in different periods, ranging between 1997 and 2014 (Fernandes et al., 2016), by focusing on the number of exporting firms at the bilateral level. We also use bilateral data on the maritime telecommunications infrastructure deployment across 171 countries and over 1990-2018 drawn from Telegeography database, by primarily considering the activation time of a bilateral digital connection through SMCs, and then using the number of SMCs connecting one country to another.

By merging the two datasets above, we build a final unbalanced panel of matched export and Internet data at the bilateral level for 48 coastal countries during the period 1997-2014, which saw the share of

Table 1: Country-level average number of exporting firms across destinations in 2009.

Country	Region	Av. # firms	Country	Region	Av. # firms	Country	Region	Av. # firms
DEU	OTHERS	3783	EGY	MENA	110	URY	LAC	30
ESP	OTHERS	1780	IRN	MENA	105	MUS	SSA	29
TUR	ECA	922	PER	LAC	103	CIV	SSA	22
BEL	OTHERS	723	LBN	MENA	83	TZA	SSA	19
BRA	LAC	500	MAR	MENA	75	KHM	EAP	17
DNK	OTHERS	467	EST	OTHERS	72	MDG	SSA	17
MEX	LAC	404	ECU	LAC	66	NIC	LAC	14
ZAF	SSA	348	HRV	ECA	58	CMR	SSA	14
PRT	OTHERS	343	GTM	LAC	54	ALB	ECA	13
NOR	OTHERS	323	CRI	LAC	52	SEN	SSA	13
PAK	SA	279	KEN	SSA	52	GEO	ECA	10
BGD	SA	155	JOR	MENA	37	YEM	MENA	8
COL	LAC	149	KWT	OTHERS	37	GIN	SSA	3
CHL	LAC	135	DOM	LAC	33			

Notes: Seven countries are out because the available period is prior to 2009 (SWE, BGR and GAB) or subsequent to 2009 (MMR, LKA, THA and STP).

cable-connected countries passing from some 40% to more than 90%.[4] Table A.1 in Appendix shows the distribution of the observations across countries and regions. Three-quarters of our sample (shares in parenthesis) are developing countries: Latin America and the Caribbean (LAC) (32%), Sub-Saharan Africa (SSA) (17.8%), Middle-East and North-Africa (MENA) (9.2%), Eastern Europe and Central Asia (ECA) (8.6%), South Asia (SA) (5.1%) and Eastern-Asia and Pacific (EAP) (2.8%). The rest of the sample (OTHERS) (24%) consists of high-income countries mostly located in Western Europe.[5]

By focusing on the most common year across countries, i.e. 2009, Table 1 displays a large country heterogeneity in the average number of exporting firms across destinations (from 3 in Guinea to 3,783 in Germany) and within regions (14 in Nicaragua to 500 in Brazil in LAC, and from 3 in Guinea to 348 in South Africa within SSA).

Looking at the time evolution of the average number of exporting firms across figures in Appendix B, we observe that this number is increasing in countries within EAP, ECA, and SA – except for Thailand and Bulgaria where the trend is constant. It is slightly increasing or stable in countries within OTHERS, fluctuating along a constant trend in SSA (except for Guinea and Senegal, where the trend is increasing), and more heterogeneous within MENA countries: decreasing in Iran and Yemen, increasing in Jordan, slightly stable in Lebanon and Morocco, and U-shaping in Egypt.

4.2 Empirical model

The trade benefits derived from Internet connectivity increase with the telecommunications' network size and the quality of interconnections (Katz & Shapiro, 1985; Crémer et al., 2000). Our empirical analysis

[4]Over a total of 172 coastal countries. Some countries from World Bank's EDD data have been dropped as they are not included in SMC data, mostly because they are landlocked countries.

[5]Kuwait, a high-income country located in the Middle-East, is the only non-European country.

builds on this feature to quantify the impact of direct SMC connections on firm's export participation at the bilateral level. We estimate the following baseline econometric specification, which can be derived from the structural gravity equation through the log-linearization (Anderson & Van Wincoop, 2003; Helpman, Melitz, & Rubinstein, 2008):

$$Ln\ Nexporter_{cdt} = \beta_1 \cdot SMC_{cdt} + \beta_2 \cdot SMC_{cdt} \times DC_c + \alpha_{cd} + \alpha_{ct} + \alpha_{dt} + \varepsilon_{cdt} \tag{1}$$

Where $Nexporters_{cdt}$ is the number of firms in country c exporting to destination d in year t; and SMC_{cdt} is our main variable of interest, i.e. a dummy variable taking value one if country c is connected through SMCs to given destination d in year t, zero otherwise, while DC_c is a dummy variable taking value one if country c is a developing economy and zero otherwise. Considering our discussion in subsection 3.2, we expect that $\beta_1 > 0$ and $\beta_2 < 0$, i.e. following the arrival of SMCs, firm participation in export markets, on average, increases in developed countries and decreases in developing countries. Appendix A.2 shows the summary statistics of the main variables.

Finally, we also include country-destination pair fixed effects (α_{cd}) to account for time-invariant characteristics at the bilateral level (e.g. distance), as well as country-year and destination-year fixed effects (α_{ct},α_{dt}) to control for time-varying characteristics at either country or destination level (e.g. GDP and multilateral resistance in both trading partners). Standard errors have been corrected for clustering at the bilateral level. Since the estimation of equation 1 using a linear regression technique might be inconsistent in the presence of heteroscedasticity, and does not consider the zero trade values adequately (Silva & Tenreyro, 2006), we also adopt a Poisson pseudo-maximum likelihood (PPML) model, considering the same high dimension of fixed-effects coherently with most recent studies (Larch, Wanner, Yotov, & Zylkin, 2019):

$$Nexporter_{cdt} = exp(\beta_1 \cdot SMC_{cdt} + \beta_2 \cdot SMC_{cdt} \times DC_c + \alpha_{cd} + \alpha_{ct} + \alpha_{dt}) + \nu_{cdt} \tag{2}$$

Considering that trade flows involving small and poor countries turn out to be more heteroscedastic than those involving other countries (Larch et al., 2019) and that our data mainly concern developing countries, we expect differences between PPML and OLS estimates. Since standard errors should allow for simultaneous correlations across all the three dimensions of the panel (c, d, t) we also correct standard errors for the multi-way clustering, which nests the typical practice of assuming that standard errors are only clustered within country-destination pair across time (Larch et al., 2019).

5 Empirical results

5.1 The impact of bilateral SMC arrival on the extensive margin of exports

Table 2 reports estimates of equations (2) and (3) in columns (1) and (2), respectively. Column (1) highlights that subsequent to a bilateral direct connection through SMCs, the number of exporting firms increases in developed economies and declines in developing ones, in line with our expectations. More specifically, the arrival of bilateral SMC leads to an increase in the number of exporting firms by about

11% in developed countries, as well as a decrease by about 7% in developing countries. These findings are confirmed in column (2), although with a slight different magnitude: when a bilateral SMC connection is created, the number of exporting firms increases by about 9.6% in advanced countries and declines by about 2.3% in poorer economies. We consider the empirical approach of equation (3) for the rest of the paper since it addresses several econometric issues, as highlighted above.

We also explore the possibility of heterogeneous effects of SMC bilateral deployment among developing countries, by proceeding to a geographic decomposition of the developing country interaction dummy (DCc) by developing areas: Eastern Europe and Central Asia (ECA), Latin America and Caribbean (LAC), Middle East and North Africa (MENA), South Asia (SA) and Sub-Saharan Africa (SSA). Exploring this geographic heterogeneity in column (3) stresses differences across developing areas: while the number of exporting firms in ECA and LAC increases by 9.4% and 1.7% following a bilateral SMC connection, this number decreases by 7.9% in MENA and SA countries, and by 5.4% in SSA countries. These results suggest that areas concentrating countries from the lower-middle and low-income groups, that is, MENA, SA, and SSA, are those where exporting firms lose from the bilateral connection process.

Moreover, we investigate whether our results also depend on destination heterogeneity in development stage, by interacting our main explanatory variables in equation (2) with a dummy that takes value one if the destination is a developing country and zero otherwise (DC_d). Results in column (4) suggest that the effects of improved connectivity on the number of exporting firms does not depend on whether the trading partners are similar or dissimilar in the development stage.

Overall, this first bunch of results supports that bilateral SMC deployment contributes to increase the number of exporting firms in developed countries but to reduce it in developing countries. Among developing economies, this adverse effect is more striking in countries from SA, SSA, and MENA regions, but does not seem related to export destination's development stage. This evidence therefore suggests that the SMC bilateral deployment can be beneficial for firms in developed countries, being able to adopt ICT technologies, and detrimental for firms in developing economies, due to their lower capacity to absorb Internet-related technologies.

Table 2: Bilateral-level linkage between number of exporting firms and SMC arrival.

	(1)	(2)	(3)	(4)
Dep. Var:	$lnNexporter_{cdt}$	$Nexporter_{cdt}$		
SMC_{cdt}	0.110***	0.0965***	0.0945***	0.0930***
	(0.0419)	(0.0221)	(0.0214)	(0.0293)
$SMC_{cdt} \times DC_c$	-0.180***	-0.119***		-0.105**
	(0.0529)	(0.0410)		(0.0411)
Regions of origin				
$SMC_{cdt} \times ECA_c$			0.0127	
			(0.139)	
$SMC_{cdt} \times LAC_c$			-0.0777*	
			(0.0434)	
$SMC_{cdt} \times MENA_c$			-0.159***	
			(0.0448)	
$SMC_{cdt} \times SA_c$			-0.159**	
			(0.0717)	
$SMC_{cdt} \times SSA_c$			-0.148**	
			(0.0712)	
Destination's development stage				
$SMC_{cdt} \times DC_d$				0.0123
				(0.0565)
$SMC_{cdt} \times DC_c * DC_d$				-0.0298
				(0.0676)
Country-Destination FE	YES	YES	YES	YES
Country-Year FE	YES	YES	YES	YES
Destination-Year FE	YES	YES	YES	YES
Observations	53,963	65,429	65,429	65,429
R-squared	0.978	0.998	0.998	0.998

Note: Unbalanced panel of country-destination pairs. Column (1) is based on OLS model, where standard errors are corrected for clustering at the bilateral level. Columns (2)-(3) are based on PPML model, where standard errors are corrected for multi-way clustering.

5.2 Effects on intensive margin of exports and total export value

In Table 3, we look at the effect of SMCs on average exports per firm (intensive margin) and total export value, in addition to the number of exporting firms (extensive margin). While data on extensive margin may have missing values when there are zero trade flows, data on intensive margin and total export value in the EDD database have missing values also when there is only one exporting firm at the bilateral level because of confidential issues. Consequently, we focus now only on the sub-sample of country-destination pairs that have a positive value of average export value per firm. For this reason, we replicate the regression on extensive margin ($Nexporters_{cdt}$) along with the intensive margin (Ave_Exp_{cdt}) and total export value (Exp_{cdt}). While the results on extensive margin are strongly confirmed (column (1)), we found no statistically significant effect of SMCs on intensive margin (column (2)), which implies weak effects on total export value (column (3)).

Table 3: The SMC impact on Export value, extensive and intensive margins.

	(1)	(2)	(3)
	Extensive margin	Intensive margin	Export value
Dep. Var:	$Nexpoters_{cdt}$	Ave_Exp_{cdt}	Exp_{cdt}
SMC_{cdt}	0.0866***	-0.0578	-0.0188
	(0.0195)	(0.0895)	(0.0360)
$SMC_{cdt} \times DC_c$	-0.112***	0.172	-0.142*
	(0.0400)	(0.170)	(0.0817)
Country-Destination FE	YES	YES	YES
Country-Year FE	YES	YES	YES
Destination-Year FE	YES	YES	YES
Observations	48,939	48,939	48,939
R-squared	0.998	0.888	0.999

Note: Unbalanced panel of country-destination pairs. PPML model, where standard errors are corrected for multi-way clustering.

5.3 Endogeneity test

Through the inclusion of fixed effects at the different levels, the omitted bias problem is drastically reduced. Previous studies highlighted that the arrival of SMCs is unlikely to be endogenous from the firm's perspective (Hjort & Poulsen, 2019), but the laying of SMCs could be affected by aggregate conditions, such as a country's outward orientation, which would be a source of reverse causality bias. To check this possibility, we run a simple test by including both lagged and lead values in our specification in addition to the current values of our main explanatory variables. While we expect insignificant coefficients for lead variables to exclude reverse causality, we could have significant coefficients for lagged variables since the effect of SMC can take some time. In line with our expectations, Table 4 shows that when including lagged, current and lead values in our specification, only the coefficients related to the lagged values are statistically significant, confirming that the causality runs from SMC arrival to firm participation into export market, rather than the opposite.

Table 4: Endogeneity test.

	(1)
Dep. Var:	$Nexpoters_{cdt}$
SMC_{cdt-1}	0.0759***
	(0.0176)
$SMC_{cdt-1} \times DC_c$	-0.0952**
	(0.0394)
SMC_{cdt}	0.0202
	(0.0129)
$SMC_{cdt} \times DC_c$	-0.0289
	(0.0199)
SMC_{cdt+1}	0.0469
	(0.0429)
$SMC_{cdt+1} \times DC_c$	-0.0598
	(0.0414)
Country-Destination FE	YES
Country-Year FE	YES
Destination-Year FE	YES
Observations	51,566
R-squared	0.998

Note: Unbalanced panel of country-destination pairs. PPML model, where standard errors are corrected for multi-way clustering.

5.4 Does the size or quality of bilateral connections matter?

Here, we explore the channels through which bilateral Internet connection may affect firm participation in the export markets. We expect that the effects are increasing in both size and quality of the bilateral SMC connection. We use the number of SMCs between any two countries, N_SMC_{cdt}, to address the size channel, and the risk of SMC faults induced by their exposure to seismic shocks to investigate the quality channel. It is indeed documented that such natural hazards represent an exogenous source of lower capacity for and stability of international telecommunications (Carter et al., 2009; Carter, Gavey, Talling, & Liu, 2014; Pope, Talling, & Carter, 2017; Aceto, Botta, Marchetta, Persico, & Pescapé, 2018; Cariolle, 2018; Cariolle et al., 2019).[6] The reduced benefits and increased costs of Internet access resulting

[6]First, damages incurred by SMCs reduce the benefits of international broadband connectivity by increasing latency and instability of telecommunications, and thereby, firms' communication and information search costs. Second, these shocks also increase induce expensive repairs on damaged cables, higher insurance costs, and additional costs related to the rerouting of Internet traffic towards more expensive and less-capacity cable paths, which are reported on Internet tariffs by

from SMC's exposure to shocks should hence deteriorate lower-productivity exporters' capacity to supply foreign markets, and eventually, to provoke their exit.

Therefore, to study the effects of the quality of bilateral SMC connections on firms' export participation, we compute a variable reflecting the bilateral SMC connection's exposure to seismic events, following the approach of Cariolle et al. (2019). This variable consists in firstly calculating the annual frequency of maritime seismic events occurring in the vicinity of SMC landing stations in the origin and destination countries, separately. Two distinct measures of bilateral SMC's exposure to seaquakes are then computed as follow:

$$Seaquake\_Freq1_{cdt} = SMC_{cdt} \times (Seaquake\_Freq_{ct} + Seaquake\_Freq_{dt})$$
$$Seaquake\_Freq2_{cdt} = SMC_{cdt} \times (\frac{Seaquake\_Freq_{ct} + Seaquake\_Freq_{dt}}{2})$$

where SMC_{cdt} is the bilateral SMC connection dummy. SMC's bilateral exposure to seaquakes is either approximated by the annual number of seaquakes that occurred in the vicinity of SMCs in both origin and destination countries ($Seaquake\_Freq1_{cdt}$), or by the average SMC exposure to seaquakes in origin and destination countries ($Seaquake\_Freq2_{cdt}$).

We therefore estimate the following specification:

$$\begin{aligned} Nexporter_{cdt} = exp(&\beta_1 \cdot SMC_{cdt} + \beta_2 \cdot N\_SMC_{cdt} \times DC_c + \beta_3 \cdot Seaquake\_Freq_{cdt} \\ &+ \beta_3 \cdot Seaquake\_Freq_{cdt} \times DC_c + \alpha_{cd} + \alpha_{ct} + \alpha_{dt}) + \nu_{cdt} \end{aligned} \quad (3)$$

Results are reported in Table 5. We focus on the size channel only in column (1), on the quality channel only in columns (2) and (4), and on both channels simultaneously in columns (3) and (5). First, in line with previous results, we find that an increase in the number of SMCs at the bilateral level leads a greater number of exporters from developed countries and a smaller number of exporters from developing ones. Second, we also find evidence that a decrease in quality of connections arising from a higher SMC exposure to seaquakes significantly reduces the number of exporting firms from developing countries.

These results suggest that a reduction in SMC quality as captured by an increase exposure of the SMC network to maritime seismic events, provokes additional exits of less performing firms from export markets by increasing the costs of Internet access and reducing the benefits of international telecommunications. We find no effect of SMC exposure to seaquakes in developed countries because of the collinearity with the fixed-effects explained by the low, almost null, exposure of these countries to maritime seismic events.

Conclusion

In this paper, we explore an undocumented feature of international trade patterns: whether and to what extent the digital network's densification at the bilateral level has contributed to trade creation in developed and developing countries. By providing digital interconnections between trade partners, the

telecommunication operators (Carter et al., 2014)

Table 5: Channels – Size and quality of bilateral cable connections.

	(1)	(2)	(3)	(4)	(5)
Dep. Var:			$Nexpoters_{cdt}$		
N_SMC_{cdt}	0.0219**		0.0219**		0.0219**
	(0.0111)		(0.0111)		(0.0111)
$N\_SMC_{cdt} \times DC_c$	-0.0547**		-0.0532**		-0.0532**
	(0.0225)		(0.0227)		(0.0227)
$Seaquake\_Freq1_{cdt}$		-1.20e-06	1.33e-06		
		(1.47e-05)	(1.34e-05)		
$Seaquake\_Freq1_{cdt} \times DC_c$		-0.000295**	-0.000269**		
		(0.000122)	(0.000112)		
$Seaquake\_Freq2_{cdt}$				-2.40e-06	2.66e-06
				(2.93e-05)	(2.69e-05)
$Seaquake\_Freq2_{cdt} \times DC_c$				-0.000591**	-0.000538**
				(0.000244)	(0.000225)
Observations	65,429	65,429	65,429	65,429	65,429
R-squared	0.998	0.998	0.998	0.998	0.998
Country-Destination FE	YES	YES	YES	YES	YES
Country-Year FE	YES	YES	YES	YES	YES
Destination-Year FE	YES	YES	YES	YES	YES

Note: Unbalanced panel of country-destination pairs. PPML model, where standard errors are corrected for multi-way clustering.

laying of SMCs has reduced communication and information search costs in a dramatic way, and thereby, could have increased trade flows between connected countries.

By combining data on bilateral number of exporting firms in 48 countries with an original panel dataset on bilateral SMC deployment, we document that improved bilateral digital connectivity through SMC connections has a positive effect on the number of exporting firms from developed countries, and a negative effect on the number of exporters from developing countries. This negative effect of bilateral digital connectivity on firm export participation is stronger in countries from the lower-middle and low-income groups – that is, in the Middle-East and North Africa, South Asia, and Sub-Saharan Africa.

These heterogeneous effects of digital connectivity on bilateral trade echo the lessons learned from the literature on the impact of trade cost reduction on heterogeneous firms (Melitz, 2003; Bustos, 2011). In fact, the arrival of broadband Internet through SMCs may have stimulated trade flows by reducing information and communication costs for the most productive firms, which can better supply foreign markets, as they are capable of absorbing technology upgrading. By contrast, less productive firms, which may not have the financial, human and organizational capacity to absorb the fixed-costs related to Internet technology adoption, may reduce their export participation, even exit foreign markets, due to increased international competition.

Therefore, our findings suggest to policy-makers that making a better digital technology available to firms in developing countries is a necessary but not a sufficient condition to let them better compete internationally. More efforts and investments are required to digital absorptive capacity across workers and firms.

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Appendix

Appendix A. Sample statistics

A.1. Sample: Unbalanced panel of bilateral trade of 48 countries, 1997-2014.

Country	EAP	ECA	LAC	MENA	OTHERS	SA	SSA	Total
ALB	0	702	0	0	0	0	0	**702**
BEL	0	0	0	0	2,569	0	0	**2,569**
BGD	0	0	0	0	0	1,436	0	**1,436**
BGR	0	835	0	0	0	0	0	**835**
BRA	0	0	2,832	0	0	0	0	**2,832**
CHL	0	0	1,37	0	0	0	0	**1,37**
CIV	0	0	0	0	0	0	469	**469**
CMR	0	0	0	0	0	0	1,521	**1,521**
COL	0	0	1,011	0	0	0	0	**1,011**
CRI	0	0	1,807	0	0	0	0	**1,807**
DEU	0	0	0	0	614	0	0	**614**
DNK	0	0	0	0	1,835	0	0	**1,835**
DOM	0	0	1,547	0	0	0	0	**1,547**
ECU	0	0	1,636	0	0	0	0	**1,636**
EGY	0	0	0	917	0	0	0	**917**
ESP	0	0	0	0	1,533	0	0	**1,533**
EST	0	0	0	0	582	0	0	**582**
GAB	0	0	0	0	0	0	508	**508**
GEO	0	789	0	0	0	0	0	**789**
GIN	0	0	0	0	0	0	297	**297**
GTM	0	0	1,086	0	0	0	0	**1,086**
HRV	0	805	0	0	0	0	0	**805**
IRN	0	0	0	603	0	0	0	**603**
JOR	0	0	0	1,116	0	0	0	**1,116**
KEN	0	0	0	0	0	0	1,17	**1,17**
KHM	873	0	0	0	0	0	0	**873**
KWT	0	0	0	0	188	0	0	**188**
LBN	0	0	0	658	0	0	0	**658**
LKA	0	0	0	0	0	139	0	**139**
MAR	0	0	0	1,561	0	0	0	**1,561**
MDG	0	0	0	0	0	0	617	**617**
MEX	0	0	1,941	0	0	0	0	**1,941**
MMR	242	0	0	0	0	0	0	**242**
MUS	0	0	0	0	0	0	1,319	**1,319**
NIC	0	0	1,145	0	0	0	0	**1,145**
NOR	0	0	0	0	2,795	0	0	**2,795**
PAK	0	0	0	0	0	1,36	0	**1,36**
PER	0	0	2,358	0	0	0	0	**2,358**
PRT	0	0	0	0	2,376	0	0	**2,376**
SEN	0	0	0	0	0	0	1,164	**1,164**
STP	0	0	0	0	0	0	16	**16**
SWE	0	0	0	0	1,506	0	0	**1,506**
THA	487	0	0	0	0	0	0	**487**
TUR	0	1,804	0	0	0	0	0	**1,804**
TZA	0	0	0	0	0	0	1,177	**1,177**
URY	0	0	1,541	0	0	0	0	**1,541**
YEM	0	0	0	423	0	0	0	**423**
ZAF	0	0	0	0	0	0	1,893	**1,893**
Total	**1,602**	**4,935**	**18,274**	**5,278**	**13,998**	**2,935**	**10,151**	**57,173**

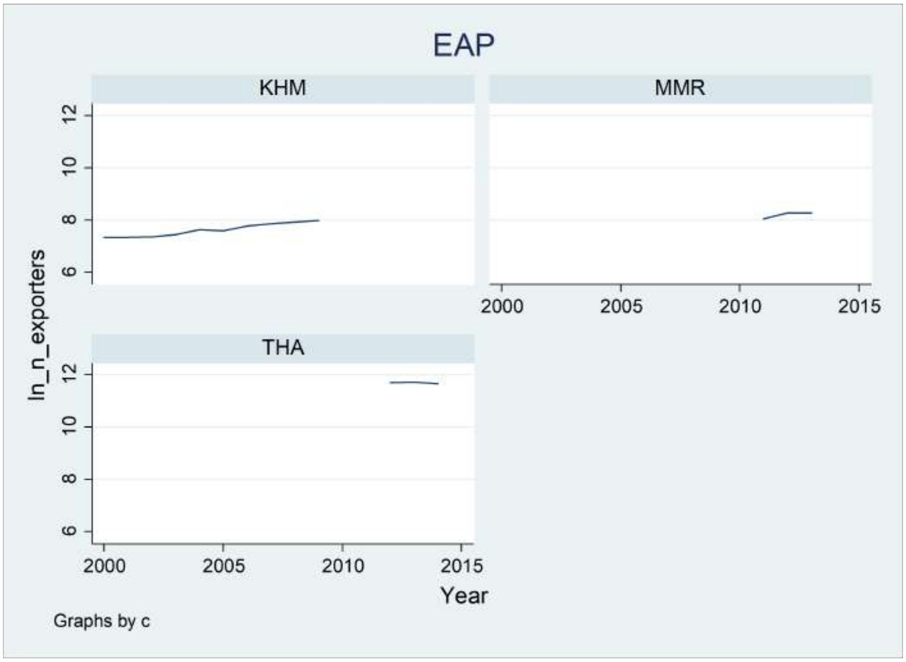
Notes: EAP = East Asia & Pacific; ECA = Europe & Central Asia; LAC = Latin America & Caribbean; MENA = Middle East & North Africa; OTHERS = Developed Economies; SA = South Asia; SSA = Sub-Saharan Africa.

A.2. Summary statistics.

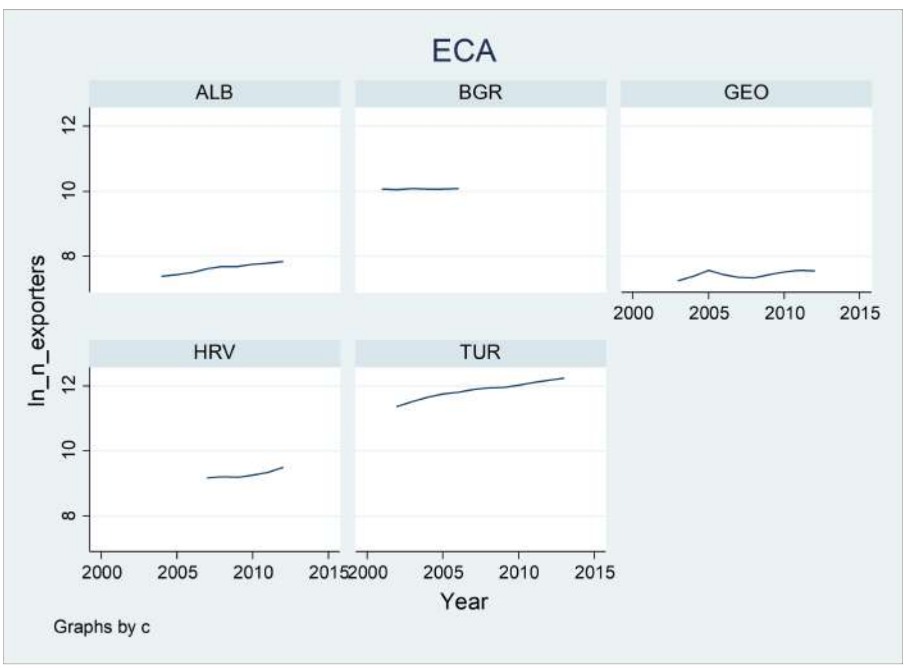
Variable	Obs	Mean	Std. Dev.	Min	Max
$N\_exporter_{cdt}$	77,448	261.038	1179.869	0	32,648
SMC_{cdt}	77,448	0.086	0.281	0	1
DC_c	77,448	.774	.418	0	1

Appendix B. Time evolution of the number of exporting firms, by developing area.

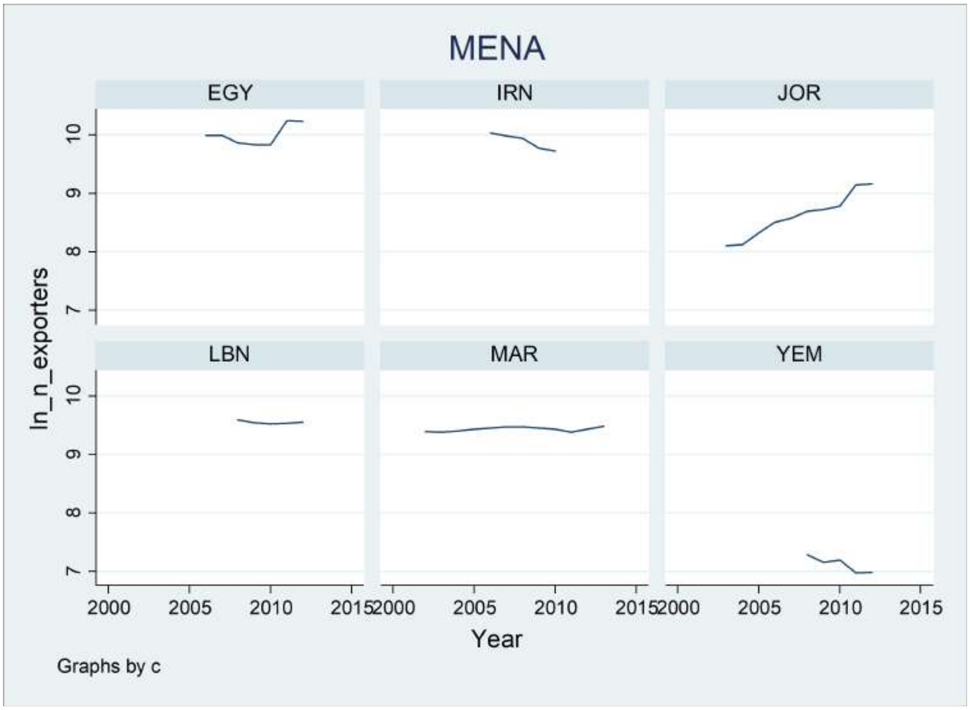
B.1. East Asia and Pacific.



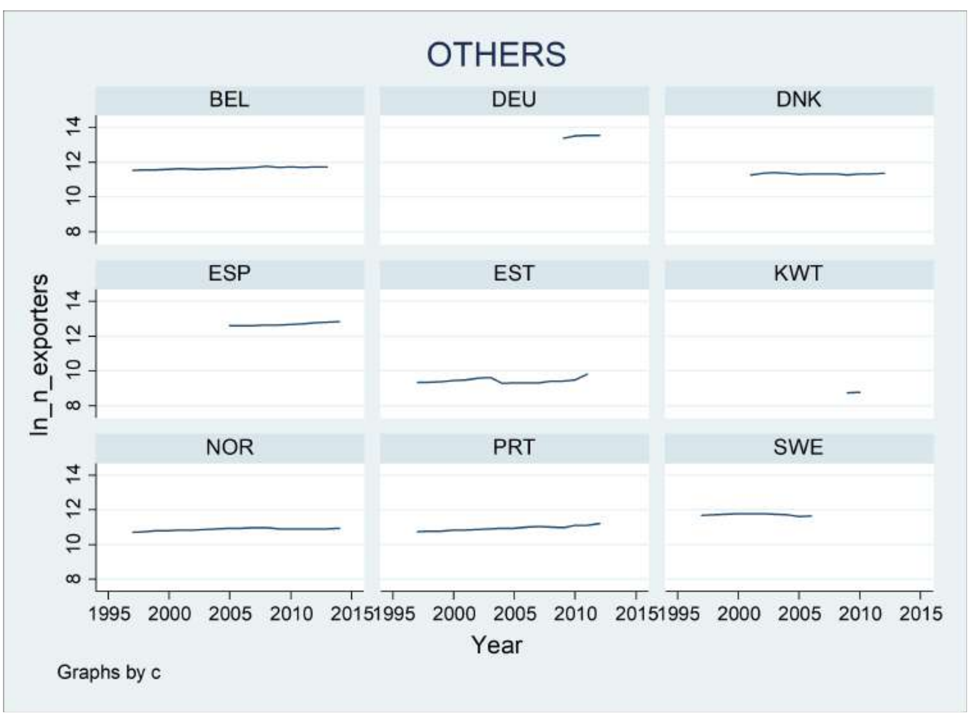
B.2. Eastern Europe and Central Asia.



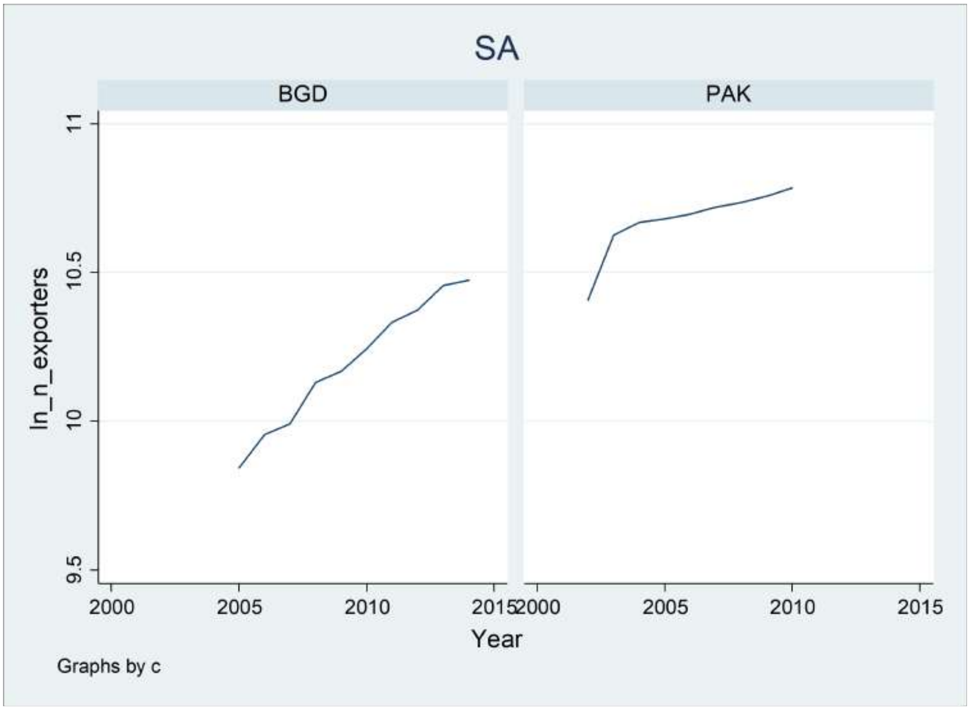
B.3. Middle East and North Africa.



B.4. Western Europe and Koweit.

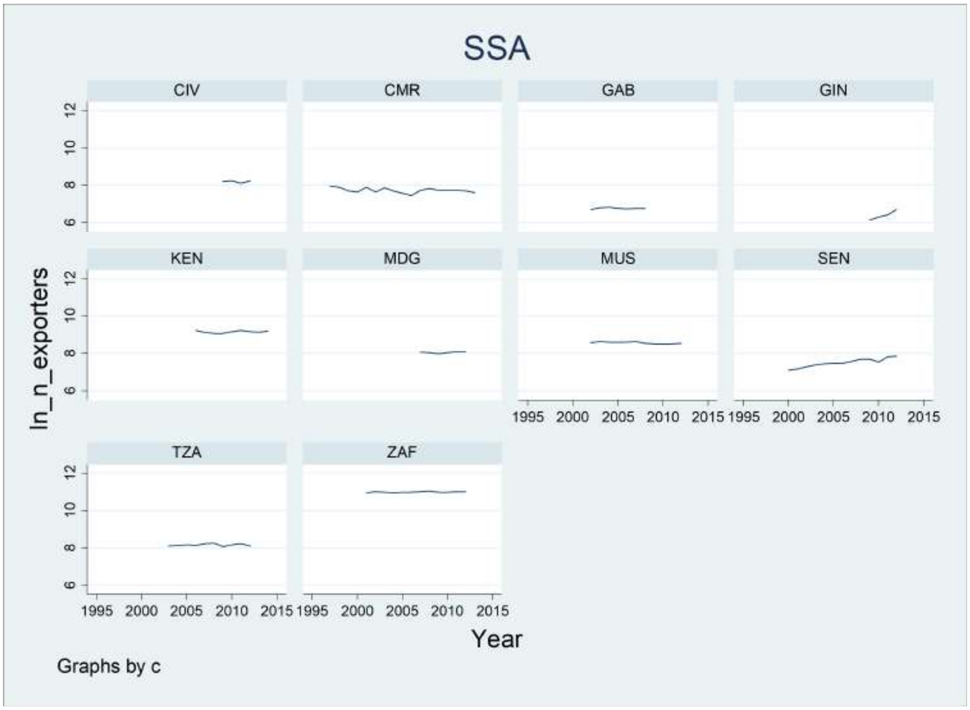


B.5. South Asia.



Notes: Sri Lanka is missing because only one-year data are available

B.5. Sub-Saharan Africa.



Notes: Sao Tomé is missing because only one-year data are available

"Sur quoi la fondera-t-il l'économie du monde qu'il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l'ignore."

Pascal

FERDi

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