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Services Trade and Internet Connectivity

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Abstract

Internet connectivity and exports of services are positively correlated. This paper presents a gravity model with bilateral measures of Internet connectivity to formalize this correlation. To establish bilateral connectivity, I construct a novel dataset based on the undersea fiber-optic cable network responsible for 99% of international data traffic. I measure the degree of bilateral connectivity using information on the capacities of these cables in order to estimate the effect of that connection on export growth between pairs of digitally connected countries. I estimate a positive relationship between Internet connectivity and bilateral exports in data-intensive industries with an elasticity of 0.25 to 2.25 over a variety of possible settings.

Keywords: Internet, trade in services, gravity

JEL codes: F14

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1 Introduction

Long records in the exchange of goods across countries have led much of the trade literature to focus on trade in goods, rather than services. But as services play a larger and larger role in modern economies - and data become increasingly available - it is a reality that trade models must account for the change in composition. The share of services in trade volumes has been rising over the last three decades, and policy makers view the service sector as a key to economic growth, export competitiveness, and poverty reduction (World Bank, 2010). At the same time, the advent of the Internet in the late 1980s has connected people all around the globe, making it easier to communicate and exchange digital data.

Anecdotally, the connection between Internet accessibility and the exchange of services is already prevalent. Call centers in India manage US tech problems from thousands of miles away, Airbnb makes traveling abroad cheaper and easier, insurance policies are traded across borders by firms halfway across the globe, and Netflix brings international entertainment at the click of a button. But capturing the effect of the Internet in economic data can prove difficult, especially when thinking internationally. Using historical data on the advent of the Internet and its international spread helps relate connectivity to the growth in bilateral service exports.

This paper explains the growth in international services trade through rising Internect connectivity in a standard gravity setting. The novelty of my approach is in creating a database of the system of underwater fiber-optic cables (Figure A.1) to measure the degree of country interconnectivity. These cables make the transfer of data in large quantities between countries possible; 99% of international data traffic between countries travels through the underwater system. By analyzing the growth in the cable system, I answer the question, "Can bilateral Internet connectivity explain the growth in services trade in recent decades?" Using data on the capacity[1] of these fiber-optic cables, I find that a one percentage point increase in connectivity correlates to a 0.25-2.25 percentage point increase bilateral exports in data-intensive services.

The value of my approach is twofold. The first is that the growth in the fiber-optic cable map provides some sense of *bilateral* connectivity. Though it will take a careful explanation of how international data flow works, the result is that my exercise returns an estimated coefficient for the strength of the connection between countries X and Y rather than more top-down approaches based on the number of Internet users or registered do-

[1] While full detail will come in Section 2, "capacity" gives a sense how much data can be transferred between two points.

main names. To clarify, consider the case of US connectivity with India and Japan. Large parts of India have low Internet access (18.0/100 persons in 2014), but Japan is very well-connected (90.6/100). Using this top-down approach, one might guess that Japanese services exports to the U.S. dwarf Indian services exports to the U.S. by 5-to-1. But the true ratio was 3-to-1 by 2008 and has continued to shrink. The reason why is that Electronic City in Bangalore is almost universally connected to the Internet (even if the rest of the country is not), and it has a high-capacity connection to the US through the submarine cable network.

The second benefit is that my point estimate provides a coefficient for the growth in trade that is targetable by policy and infrastructure. With more abstract approaches to international connectivity, the policy lever to encourage services trade is less clear. In my exercise, the answer is to build more capacity. To establish causality, I perform a separate exercise, wherein I apply the "routing" identification strategy of Chandra and Thompson (2000), Michaels (2008), and Fajgelbaum and Redding (2014). Whereas my above-mentioned results tie together bilateral connectivity and services trade growth, there is an obvious endogeneity problem: countries build submarine cables between one another with the intention of increasing capacity, possibly for trade in services. I seek to show an effect where cable connectivity is *unexpected*. The "routing" idea is as follows: suppose Country A wants to connect to some Country C, and vice versa. To do so, they have to pass through Country B. Though Country B has made no plans of its own to connect to Country A and Country C, it now has access to the cable system. I then measure whether B's service trade with A and C grows.

While cables between North America and Europe and between East Asia and North America came online very quickly, Western Europe was without the reliability of a high-capacity fiber-optic undersea cable to Eastern Asia until recently. Building such a cable, such as the FLAG Europe-Asia cable in 1997, necessitates stopping points in Egypt and along the southeast Asian coast. I find that increasing cable capacity by 1 percentage point yields a 2.25 percentage point increase in data-intensive services exports along the cable line in the case of Egypt, or a 1.82 percentage point increase in a broader set of countries along the cable lines.

My research is consistent with previous papers providing evidence on the association between Internet connectivity and trade in services. Freund and Weinhold (2002) and Freund and Weinhold (2004) present evidence that Internet connectivity is related to growth in services trade, in terms of both exports and imports, where their connectivity measure is the number of web hosts attributed to each country. A more recent paper by Bojnec and Fertő (2010) relates Internet connectivity to manufacturing trade, where the relevant variable is number of Internet users per country. Their results show that Internet access is related to better access to information, an increase in competition, and a reduction of trade costs. Guerrieri and Meliciani (2005) also address the relationship between communications technologies and producer services. A recent working paper by Eichengreen et al. (2016) relates cable connectivity and electronic currency trading, but their focus is on the foreign exchange market.

My work also contributes to the research on the relationship between information and trade of Steinwender (2014). She shows that the establishment of the transatlantic telegraph in 1866 allowed for price information to move from the UK to the US nearly instantaneously, a huge improvement from waiting for the next ship to make the journey across the Atlantic and deliver new price information. Average trade flows increased after the telegraph transmitted data on demand shocks more quickly. It is my goal to extend this type of analysis into the Information Age.

Lastly, my work adds to the "gravity" literature of international trade. I augment the empirical approach by providing a time-dependent, bilateral measure of connectivity for services exports. My results are consistent with one where submarine cables reduce trade costs between countries. In this view, bilateral connectivity makes certain services cheaper to export and incentivizes growth in industries with relatively high data requirements. My modeling will also be consistent with the emerging literature on the econometric issues with zeros in trade data, e.g. Silva and Tenreyro (2006), that I will address in robustness checks.

The map of the discussion is as follows. Section 2 details the workings of the Internet and data transfer, catalogs the history of submarine cables, and explains the importance of modern day fiber-optic cables. Section 3 explains the data. Section 4 explains my estimation strategy and presents results. Section 5 suggests some extensions of my work. Section 6 concludes.

2 The Internet and Cable History

Before presenting the model, it will aid the reader to have a fuller understanding of the relevant history of long-distance data transfer and how the Internet works.[2]

First, a few words of terminology will help. A *bit* is a zero or a one. All data are made up of bits: 8 bits are a byte, 1,024 bytes are a kilobyte, 1,024 kilobytes are a Megabyte

[2] What will be presented here is still a simplification. For a more thorough explanation, I would suggest Rus Schuler's White Paper on the Internet (https://web.stanford.edu/class/msande91si/www-spr04/readings/week1/InternetWhitepaper.htm).

(MB), 1,024 MB are a Gigabyte (GB), and 1,024 GB are a Terabyte (TB). An email is on the order of a handful of kilobytes, whereas a PDF of this paper is a few MBs. A present-day laptop's disk holds around 1TB or more. A *bit-rate* is a measurement of bits-per-time, which is the data equivalent of measuring miles-per-hour – X bits moving at Y bits-per-second tells you how long it takes to get those bits between two locations. *Bandwidth* refers to the maximum bit-rate of available or consumed information capacity. Bandwidth is also rate – the bit-rate of a given medium is capped by the available bandwidth. The rate of successful delivery over a communication channel, such as a cable, depends on the limitations of this underlying medium (copper cables versus fiber-optic ones), the available processing power of the system components (how good your computer is), and end-user behavior. Sending an email doesn't require much bandwidth, but a Skype call does.

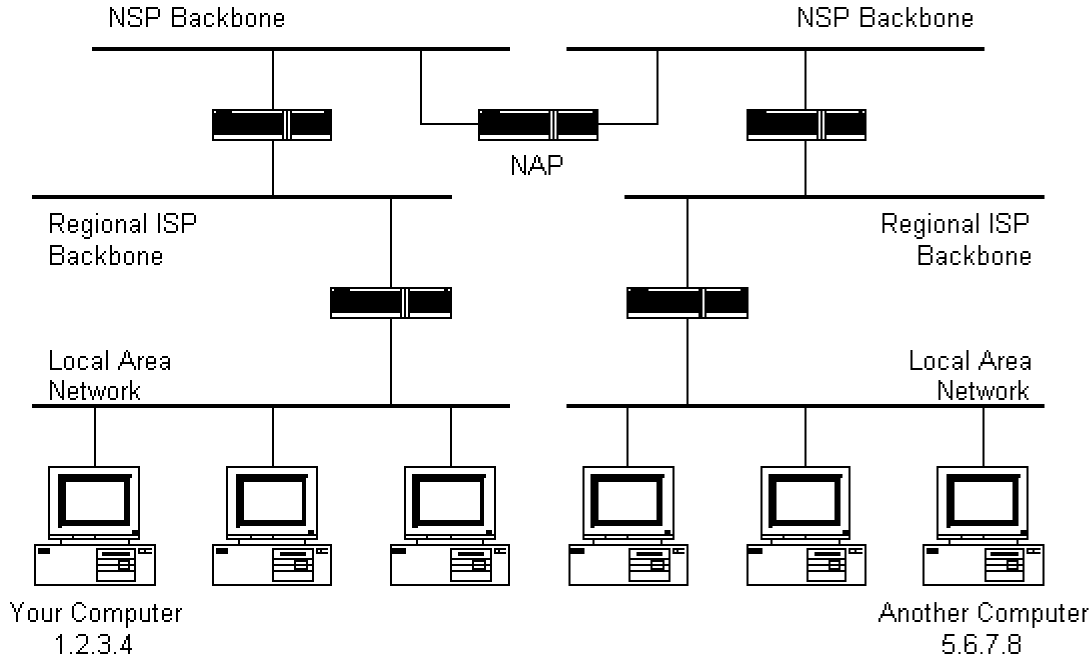
If two computers want to "talk" to each other, say via email, there must be some connection between them.[3] Each computer has an Internet Protocol Address (IP Address) and sends messages through a series of interconnected routers to another computer. In Figure 1, a computer at IP address 1.2.3.4 can transfer data to the computer at IP address 5.6.7.8 through a Network Access Point. In my international case, think of Network Access Points connected to each other through the undersea cable network. No matter the hardware at either end of the connection, the underlying medium (the cable) will dictate the bandwidth that is available between two end users. I'm interested in measuring the value of (and the growth in) the bandwidth of these cables, which I will refer to throughout the paper as the cable's "capacity."

The last bit of subtlety about bandwidth is in how it's measured: bits per second from point A to point B. You could put a bunch of hard drives in a jet and transfer a lot of bits per second from France to Egypt, but if you're swapping messages a conversation could only progress after each time the jet landed. Cables, on the other hand, can transmit very quickly but in smaller quantities. But therein lies the value of modern fiber-optic cables: high speeds *and* high bandwidth.

While countries have been connected via telegraph and coaxial telephone cables since the first transatlantic cable in 1866, the advent of fiber-optic cables allowed for high enough bandwidth in order to make some services trade viable. The first copper wires could transfer 10-12 words per minute; now businesses thousands of miles apart can interact over Skype. Fiber-optic cables use lasers in a glass tube that permit higher signal speeds ($\sim$200,000 km/s) at higher capacities than their predecessors. TAT-8, the first sub-

[3]Satellites account for less than 1% of international data flow and are often used for very remote locations.

Figure 1: Organization of Data Transfer



ISP stands for Internet Service Provider, NSP stands for Network Service Provider, and NAP stands for Network Access Point. NAPs are also known as Internet Exchange Points (IXPs).
Source: https://web.stanford.edu/class/msande91si/www-spr04/readings/week1/InternetWhitepaper.htm

marine fiber-optic cable, connected France, Britain, and the US in late 1988 with a capacity of 40,000 telephone channels, an order of magnitude increase in capacity over contemporary coaxial cables.

The new fiber-optic cables were still not without problems, however. Initial fiber-optic cables were attacked by sharks due to a lack of electrical shielding. Fishing trawlers and anchors would still regularly break cables. To adapt, cables were woven in self-healing fiber rings to increase redundancy (and thus reliability). Cables began being buried in the seabed floors to avoid human destruction. PTAT-1 and cables that followed it were fitted with shielding to avoid becoming fish food. Around the same time, the development of submarine branching units allowed multiple destinations to be served by a single cable. The world was more and more becoming connected by reliable, high-capacity cables that far outstripped the previously laid coaxial cables.

The submarine fiber-optic cable system laid mostly after 1990 represents a discontinuous jump in speed and capacity from its coaxial and telegraphic predecessors. Cables are still occasionally broken by anchors and natural disasters, but the incidence of submarine cable faults is very low (0.44 faults per 1000km per year after 1985 vs. a 1991 report of 2.13 for conventional buried cables). As a result, the construction of fiber-optic cables between two countries provides a reliable, high-capacity avenue for data transfer. In the empirical section, I will show that the country linkages provided by these cables is correlated with increased exports of data-intensive services.

3 Data

Data on the undersea fiber-optic cables come from several sources. My primary source is TeleGeography's Global Bandwidth research, a telecommunications market research and consulting firm whose primary research areas include international Internet networks, undersea cables, capacity, and long-distance traffic. They provide information on active and planned submarine cable systems with a maximum upgradeable capacity of at least 5 Gb/s, including ready-for-service date, length, owners, and landing point. As of the writing of this paper, there are data on 347 extant and planned cables, beginning in 1989.

These data are supplemented by the Submarine Cable Almanac, put together by the Submarine Telecoms Forum. Remaining possible gaps in cable lines and cable capacities were scraped from http://www.cablemap.info/ and cable-specific websites (e.g. http://www.smw3.com/ for SEA-ME-WE 3). I end up with a final sample of 254 cables that are relevant to my study (I exclude future planned cables, cables only connecting small island chains outside of my study, etc.). Wherever available, I include data on the capacity of each cable. In general, I am able to find the capacities of all large and major cables, though data on older and smaller cables often lack reliable measures of capacity. As a result, my usable sample for capacity comprises 138 cables with measures of available bandwidth.

To measure connectivity, I use the cable data in two different ways. The first is to use the broadest set of information available, namely the raw number of cables and the countries they connect. In this case, there will be higher connectivity between countries for which there are a more cables: this measure is an integer value. The second measure uses all the available capacity data. Since cables range in capacity by two orders of magnitude, a more accurate measure of connectivity would be to use the sum of these capacities for any country pair. For further detail on these two measures, see Appendix A.

The services trade data come from the World Integrated Trade Solution (WITS), which is a collaborative effort between the World Bank, United Nations Conference on Trade and Development, United Nations Statistical Division, and World Trade Organization. These data comprise bilateral exports/imports between country-pairs on trade partners around the globe by BOP disaggregation. I perform my analysis at the 2-digit and 3-digit levels and find similar results. While data at the 3-digit level are more precise, the drawback is that many countries do not report trade flows at this level of specificity. As such, I use the 2-digit in all cases when describing my results. See Table A1 for a full list of countries and Table A3 for a list of sectors.

Ex ante one might expect that Internet access has different effects for different service industries; Skype doesn't make it easier to give an intercontinental haircut. To capture this idea, I separate services into two groups: data-intensive services (DIS) and all else (non-DIS). To determine which sectors are "data-intensive," I use the World Input-Output Database (WIOD) to measure the input ratio of telecommunications in each sector. I find that financial services, computer & information, and other business services are the most data dependent.[4] My estimation strategy will use a dummy for DIS interacted with connectivity to test if there is a different effect for these sectors.

The goods trade information comes from the World Trade Flows data compiled by Robert Feenstra of the Center for International Data. These data similarly comprise bilateral exports, though I lack the sector break-out that is available for our services data.

4 Estimation

As mentioned above, one can view the change in cable connections and capacity to be akin to a time-varying change in the distance variable in a traditional gravity model. I rely on the source-destination-year variation in the cable network in order to estimate the correlation between inter-country service exports and connectivity. In order to soak up the variation due to country size, cultural similarities, geography, and other covariates, I include fixed effects at the source-sector-year level, the destination-sector-year level, and the source-destination-sector level.

Recall that the goal is to measure the effect of the variability in fiber-optic connections between countries. This variance occurs over time, t, between a source country, i, and a destination country, n, for all sectors, s, in a given pair. I therefore prefer an estimating equation taking the stochastic form

$$X_{inst} = \beta_0 \, cables_{int}^{\alpha} \, e^{\theta_{ins} d_{ins} + \theta_{ist} d_{ist} + \theta_{nst} d_{nst}} e^{\eta_{inst}}, \tag{1}$$

[4] In particular, I find Financial Intermediation, Other Business Activities (which includes Computer and Related Services), and Air Transport to have the largest inputs from the telecommunication sector. The relevance of Air Transport is driven almost entirely by the United States in the WIOD sample, so I exclude it.

or, taking logs,

$$ln(X_{inst}) = ln(\beta_0) + \alpha\ cables_{int} + \theta_{ins}d_{ins} + \theta_{ist}d_{ist} + \theta_{nst}d_{nst} + \eta_{inst}, \tag{2}$$

where X_{inst} represents exports from i into n in esctor s at year t, $cables_{int}$ represents a measure of cable connectivity between a country pair in time t, d_{ins} is a source-destination-sector fixed effect, d_{ist} is a source-sector-time fixed effect, and d_{nst} is a destination-sector-time fixed effect. As described in Section 3, my measure of $cables_{int}$ will take two forms: 1) The raw number of cables, i.e. the coefficient will be a semi-elasticity between cable number and log point increase in exports; and 2) The logged capacity (GB/s) of all cables between two countries, i.e. the coefficient is an elasticity between the log point addition in cable capacity and the log point increase in exports.

Since I allow for a difference in the effect of cables on my two groups of services sectors, my main estimation equation will take the form

$$\begin{aligned} ln(X_{inst}) =& ln(\beta_0) + \gamma_1 \mathbb{I}\{DIS\ sector\} \times cables_{int} \\ &+ \gamma_2 \mathbb{I}\{non-DIS\ sector\} \times cables_{int} \\ &+ \gamma_3 \mathbb{I}\{goods\ sector\} \times cables_{int} \\ &+ \theta_{ins}d_{ins} + \theta_{ist}d_{ist} + \theta_{nst}d_{nst} + \eta_{inst}, \end{aligned} \tag{3}$$

where γ_1 and γ_2 are the parameters of interest.

Table A4 presents the results for the full sample using all available data. All standard errors are clustered at the source-destination level. Exports in services increase across the board, but the coefficients for DIS are nearly double those of other services. The measure using cable capacity delivers more precise estimates than that using only raw cable number. As not all cables are created equal, this result supports the idea that growth in services trade is correlated with growth in capacity. These results are robust to several additional considerations. See Section 4.2 for full detail.

I readily admit that, when considering the full sample, these results tell only a correlative story. There is clear endogeneity in the regressors as infrastructure projects are not exogenous. In the following section, I discuss an identification strategy that establishes two possible cases where connections to cables could be exogenous.

4.1 Identification

I follow the "routing" identification strategy of Chandra and Thompson (2000), Michaels (2008), and Fajgelbaum and Redding (2014). The obvious endogeneity is that cables will be built where there is a desire for them. Then the construction of cables will be correlated with higher services trade due to projected growth rather than admitting any sort of causal story; providing reliable capacity to a country would not promote service trade, rather the desire for a cable is only indicative of underlying services growth. The main idea behind "routing" is that while the infrastructure assignment is non-random, locations can be treated with cable infrastructure for a reason aside from characteristics unobserved to the econometrician: these places happen to lie along the route between two other important locations. In the case of the fiber-optic cables between Western Europe and East Asia, the funding for the construction came mostly from the telecom companies at either end rather than countries in between. I consider two possible stories: 1) All countries not in Western Europe or East Asia[5] received cable connections due to routing; 2) Egypt – due to the presence of the Gulf of Suez, the Red Sea, and the Gulf of Aden – is routed through only because it provides the shortest possible land route between the two bodies of water abutting Europe and East Asia. In particular, there exist four such cables (Figures A.2, A.3, A.4, A.5) that have landing points in between the Europe-East Asia route. In this empirical exercise, I consider the effect that connectivity with these cables increases services trade between the connected countries, but not other nearby countries.

Tables A5 and A6 present the results for regression equation 3.[6] In this case, only the coefficient on exports for data-intensive services is positive. Other services remain flat or even decline. The magnitudes are much larger than those of the previous exercise, suggesting that these individual countries tend to expand their DIS exports faster than the countries who are responsible for routing the cables. As it remains unclear why other services would decline with the expansion of Internet connectivity, these results push me again to favor my measurement using cable capacities.

4.2 Robustness

I provide robustness checks to three anticipated concerns: 1) Only the first cable connection matters; 2) The importance of cable connectivity is nonlinear; and 3) The dropped zeros in the gravity equation are driving the results.

[5] A list of these countries is presented in Table A2.

[6] For the exercise with Egypt as the only source country, the destination-sector-time and source-sector-time fixed effects are replaced with year dummies to identify the effects.

4.2.1 Single Cable

Consideration of my results and identification strategy might lead one to suspect that only the first connection to a fiber-optic cable is important. Table A7 presents my estimates for coding a cable variable with a maximum value of 1: any additional cable connections are seen as redundant. The weak precision in these estimates suggests that a single cable's connection does not do a very good job at capturing the full effect. As previous results suggested that the capacity measurements do a relatively better job, it is not surprising that the single-cable results do not tell the full story.

4.2.2 Quadratic Term

It may be the case that the relationship between connectivity and service trade is nonlinear. To test this hypothesis, I rerun all of the capacity regressions with a quadratic term included. Table A8 presents the results. Here, the coefficients are consistent with a story of only higher connections mattering: the quadratic is positive while the linear coefficient is negative. This result pairs nicely with my findings on single cable connections, as the first cable is likely to have the least capacity.

4.2.3 Zeros

Research into the zeros in trade data neccessitates the consideration of other estimation procedures that can account for them. In particular, Santos Silva & Tenreyro address the bias in estimates of the gravity model under heteroskedasticity. They advise use of a Poisson pseudo-maximum likelihood estimatation (PML) that performs significantly better in the presence of heteroskedasticity. However, due to the high dimensionality in the fixed effects I use for estimation, I can only present results here for a smaller sample. Table A9 presents the results for the case of Egypt. The results for DIS remain consistently positive, but the PML procedure yields strongly negative coefficients for other services. As this latter result is a bit puzzling, I leave it as an area for future research.

5 Extensions

The use of this new source of data, the undersea fiber-optic cable network, raises many questions that I am not able to answer in my current analysis. I address a few of them here as avenues for further research.

My analysis has mainly focused on bilateral connections as measured by landing sites for the various cables. This measure precludes landlocked countries in the data from receiving any effect from cable connectivity. In practice, this is not quite right. While Switzerland's access to the United States will be gated by any existing under*ground* cables connecting it to a coastal country, it may certainly make use of a France-to-U.S. undersea fiber-optic cable once data make it to the Atlantic. With more data on land routes for communications infrastructure, one would be able to estimate the effect of coastal cables on inland countries who will have less control over cable placement, giving a sound identification structure.

If cable connectivity is as good an indicator of service sector export growth as I have measured (for specific service sectors), one could use the cables as an IV for the effect of service growth on total country growth. The World Bank's position is that the service sector is vital to overall domestic welfare, so any expansion thereof should have substantial welfare implications.

Lastly, this research question could also speak to the idea of "blueprint" transfer in FDI as in Keller (2001). A branch of future research could use the Internet connectivity measure as a clearer mechanism for the transfer of ideas via FDI; transfer of inventions is likely higher through the Internet than embodied in goods trade.

6 Conclusion

By creating a dataset of the undersea fiber-optic cable network, I find that improving bilateral Internet connections promotes bilateral service trade in data-intensive sectors. I argue that this effect is true both in the aggregate world economy and in particular for a smaller subset of countries for whom I argue the cable connections to be exogenous. Service sectors in finance, computers and information, and other business services tend to have the greatest effects.

References

Bojnec, Štefan and Imre Fertő, "Internet and international food industry trade," *Industrial Management & Data Systems*, 2010, *110* (5), 744–761.

Chandra, Amitabh and Eric Thompson, "Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system," *Regional Science and Urban Economics*, 2000, *30* (4), 457–490.

Eichengreen, Barry, Romain Lafarguette, and Arnaud Mehl, "Cables, sharks and servers: Technology and the geography of the foreign exchange market," Technical Report, National Bureau of Economic Research 2016.

Fajgelbaum, Pablo and Stephen J Redding, "External integration, structural transformation and economic development: Evidence from argentina 1870-1914," Technical Report, National Bureau of Economic Research 2014.

Freund, Caroline and Diana Weinhold, "The Internet and international trade in services," *American Economic Review*, 2002, *92* (2), 236–240.

Freund, Caroline L and Diana Weinhold, "The effect of the Internet on international trade," *Journal of international economics*, 2004, *62* (1), 171–189.

Guerrieri, Paolo and Valentina Meliciani, "Technology and international competitiveness: The interdependence between manufacturing and producer services," *Structural change and economic dynamics*, 2005, *16* (4), 489–502.

Keller, Wolfgang, "Knowledge spillovers at the world's technology frontier," 2001.

Michaels, Guy, "The effect of trade on the demand for skill: Evidence from the interstate highway system," *The Review of Economics and Statistics*, 2008, *90* (4), 683–701.

Silva, JMC Santos and Silvana Tenreyro, "The log of gravity," *The Review of Economics and statistics*, 2006, *88* (4), 641–658.

Steinwender, Claudia, "Information frictions and the law of one price:" When the States and the Kingdom became United"," Technical Report, WTO Staff Working Paper 2014.

Appendix A Cable Network Data

When constructing the cable network dataset, I am forced to make a decision on how to quantify a bilateral pair's connectivity. One approach would be to create a dichotomous variable that takes a value of one whenever at lease one cable links two countries (as is the case in Table A7). In this interpretation, the relevant factor is whether two countries are connected through a submarine cable at all. To better replicate the nature of data transfer, however, I would like to use a more nuanced measure of the capacity of connectivity between two points.

With the data available to me, I can make two possible refinements. I can include a cummulative total of the connecting cables between two countries, or I can measure the available bandwidth between those two countries. As more cables increase the available bandwidth between two endpoints, these two measures are highly correlated. They are not identical, however, as each cable is not identical in the bandwidth it provides. The capacities of cables have grown over time, and there is also significant variation within a given year. This latter form of variation is often due to geographical anomalies requiring low-capacity cables to service small islands. As an example, the 2011 Europe-India Gateway is a high-capacity cable connecting two continents whereas the 2011 Energinet Laeso-Varberg cable connects the Danish island of Laeso to Varberg, Sweden. Without taking capacity into account, these connections would be face neutral.

From a technological perspective, using the capacity measurement would be a better solution over the cable count. Unfortunately, some of the smaller cables do not publically list their capacities. As a result, I use both measures in my estimation and analysis. The gravity regression results tell similar stories between the two measurements. I prefer the capacity results over the raw cable count as the coefficient is more interpretable – log points of capacity translate to log points of services exports rather than translating an integer of cables to log points of services exports.

Table A1: List of Countries

Afghanistan	Dominican Republic	Kenya	Puerto Rico
Albania	Ecuador	Korea	Qatar
Algeria	Egypt	Kuwait	Reunion
American Samoa	El Salvador	Kyrgyzstan	Romania
Andorra	Equatorial Guinea	Latvia	Russia
Angola	Estonia	Lebanon	Rwanda
Argentina	Ethiopia	Liberia	Samoa
Armenia	Fiji	Libya	Saudi Arabia
Australia	Finland	Lithuania	Senegal
Austria	France	Luxembourg	Serbia
Azerbaijan	French Guiana	Madagascar	Seychelles
Bahamas	French Polynesia	Malaysia	Singapore
Bahrain	Gabon	Maldives	Slovakia
Bangladesh	Gambia	Mali	Slovenia
Belarus	Georgia	Malta	Somalia
Belgium	Germany	Mauritania	South Africa
Belize	Ghana	Mauritius	Spain
Benin	Gibraltar	Mayotte	Sri Lanka
Bermuda	Great Britain	Mexico	Sudan
Bhutan	Greece	Moldova	Suriname
Bolivia	Greenland	Mongolia	Sweden
Bosnia & Herzegovina	Grenada	Montenegro	Switzerland
Brazil	Guadeloupe	Morocco	Syria
Brunei	Guam	Mozambique	Taiwan
Bulgaria	Guatemala	Myanmar	Tajikistan
Cambodia	Guinea	Namibia	Tanzania
Cameroon	Guyana	Nepal	Thailand
Canada	Haiti	Netherlands	Togo
Cayman Islands	Honduras	New Zealand	Tonga
Central African Republic	Hong Kong	Nicaragua	Tunisia
Chad	Hungary	Niger	Turkey
Chile	Iceland	Nigeria	USA
China	India	Norway	Uganda
Colombia	Indonesia	Oman	Ukraine
Congo (Dem. Rep. of)	Iran	Pakistan	United Arab Emirates
Costa Rica	Iraq	Palestine	Uruguay
Cote d'Ivoire	Ireland	Panama	Uzbekistan
Croatia	Israel	Papua New Guinea	Venezuela
Cuba	Italy	Paraguay	Viet Nam
Cyprus	Jamaica	Peru	Virgin Islands (Brit.)
Czech Rep.	Japan	Philippines	Yemen
Denmark	Jordan	Poland	Zambia
Djibouti	Kazakhstan	Portugal	Zimbabwe

Table A2: Routing Subsample

Bangladesh	Jordan	Pakistan	Thailand
Djibouti	Lebanon	Philippines	Tunisia
Egypt	Malaysia	Saudi Arabia	United Arab Emirates
India	Morocco	South Africa	

Table A3: List of Service Sectors

200 Total EBOPS Services	249 4 Construction services
205 1 Transportation	250 4.1 Construction abroad
206 1.1 Sea transport	251 4.2 Construction in the compiling economy
207 1.1.1 Passenger	253 5 Insurance services
208 1.1.2 Freight	254 5.1 Life insurance and pension funding
209 1.1.3 Other	255 5.2 Freight insurance
210 1.2 Air transport	256 5.3 Other direct insurance
211 1.2.1 Passenger	257 5.4 Reinsurance
212 1.2.2 Freight	258 5.5 Auxiliary services
213 1.2.3 Other	260 6 Financial services
214 1.3 Other transport	262 7 Computer and information services
215 1.3.1 Passenger	263 7.1 Computer services
216 1.3.2 Freight	264 7.2 Information services
217 1.3.3 Other	266 8 Royalties and license fees
218 1.4 Space transport	268 9 Other business services
219 1.5 Rail transport	269 9.1 Merchanting and other trade-related services
220 1.5.1 Passenger	270 9.1.1 Merchanting
221 1.5.2 Freight	271 9.1.2 Other trade-related services
222 1.5.3 Other	272 9.2 Operational leasing services
223 1.6 Road transport	273 9.3 Miscellaneous business, professional, and technical services
224 1.6.1 Passenger	274 9.3.1 Legal, accounting, management consulting, and public relations
225 1.6.2 Freight	275 9.3.1.1 Legal services
226 1.6.3 Other	276 9.3.1.2 Accounting, auditing, bookkeeping, and tax consulting services
227 1.7 Inland waterway transport	277 9.3.1.3 Business and management
228 1.7.1 Passenger	278 9.3.2 Advertising, market research
229 1.7.2 Freight	279 9.3.3 Research and development
230 1.7.3 Other	280 9.3.4 Architectural, engineering, and other technical services
231 1.8 Pipeline transport/electricity transmission	281 9.3.5 Agricultural, mining, and on-site processing services
232 1.9 Other supporting/auxiliary transport services	282 9.3.5.1 Waste treatment and depollution
236 2 Travel	283 9.3.5.2 Agricultural, mining and other on-site processing services
237 2.1 Business travel	284 9.3.6 Other business services
238 2.1.1 Expenditure by seasonal/border workers	285 9.3.7 Services between related enterprises, n.i.e.
239 2.1.2 Other	287 10 Personal, cultural, and recreational services
240 2.2 Personal travel	288 10.1 Audiovisual and related services
241 2.2.1 Health-related expenditures	289 10.2 Other personal, cultural, and recreational services
242 2.2.2 Education-related expenditures	291 11 Government services, n.i.e.
243 2.2.3 Other	292 11.1 Embassies and consulate
245 3 Communications services	293 11.2 Military units and agencies
246 3.1 Postal and courier services	294 11.3 Other government services
247 3.2 Telecommunications services	

Sectors in blue are considered data-intensive as measured by telecommunications input in WIOD.

Figure A.1: Cable Map

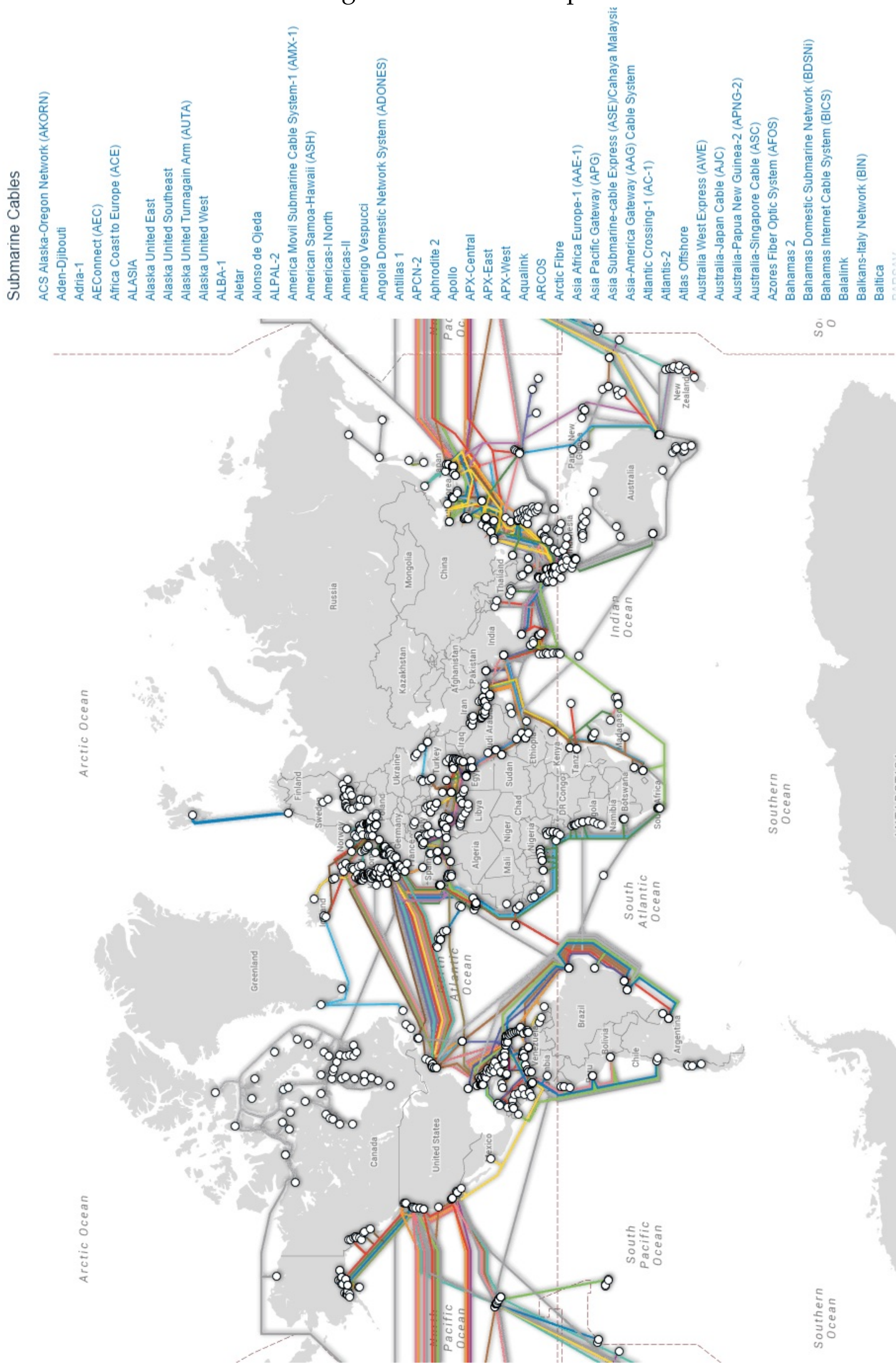


Figure A.2: FEA

Figure A.3: SEA-ME-WE 3

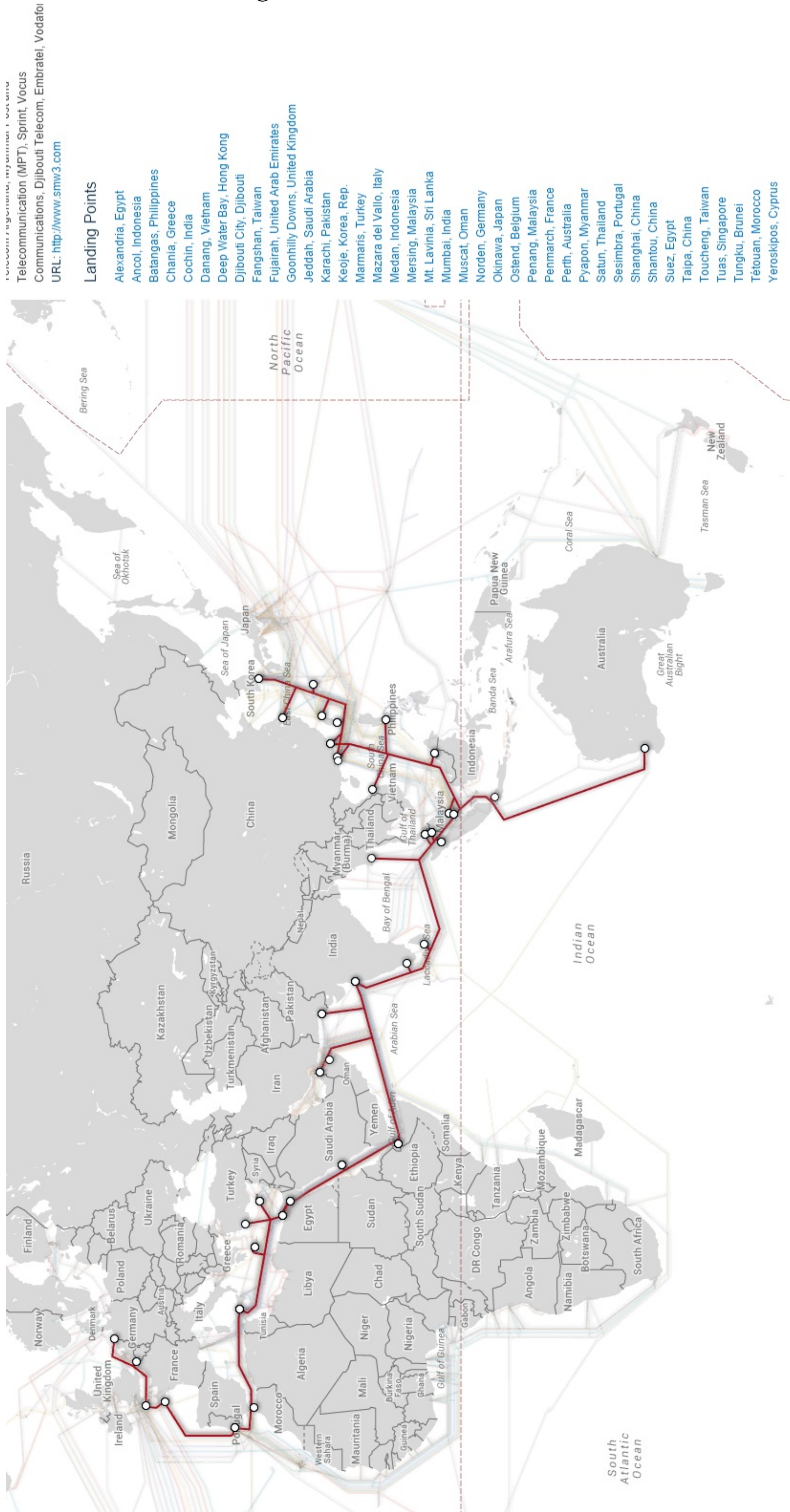


Figure A.4: SEA-ME-WE 4

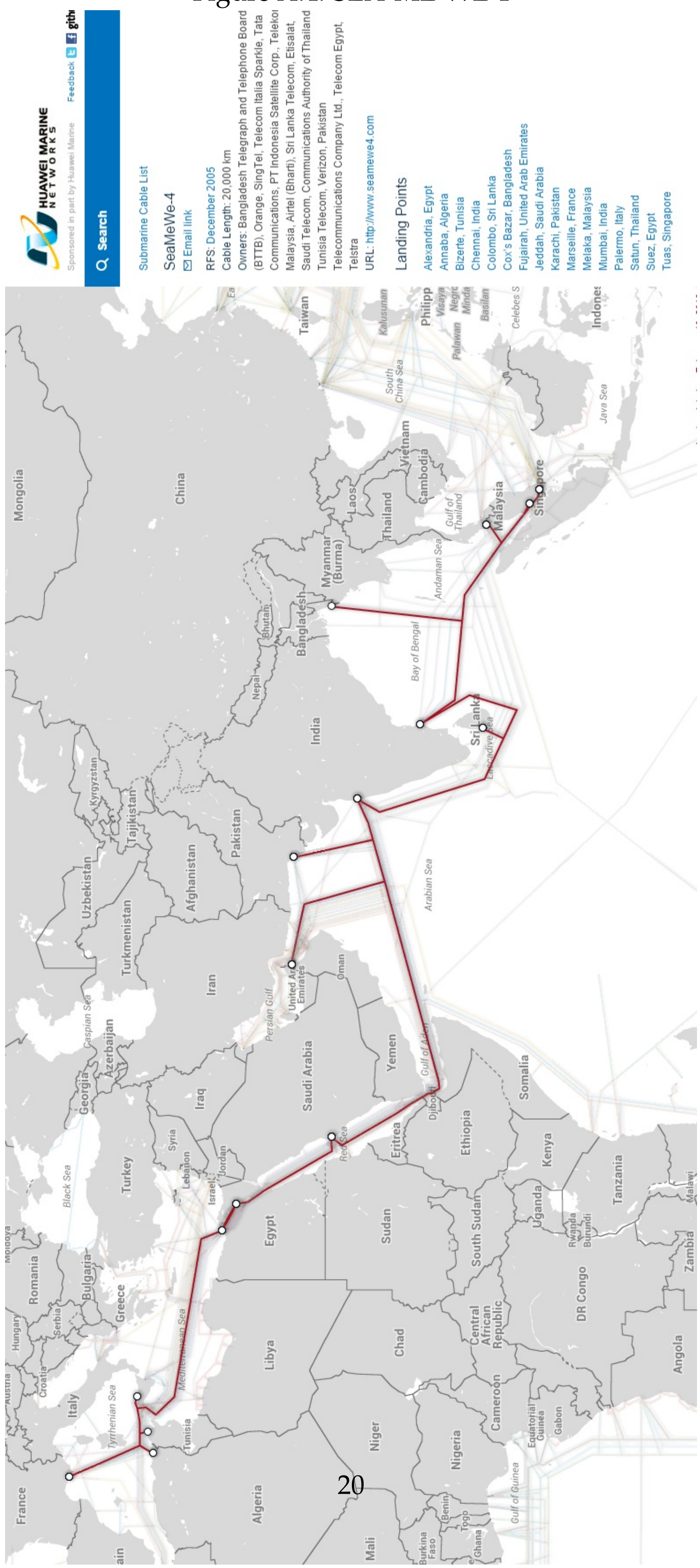


Figure A.5: IMEWE

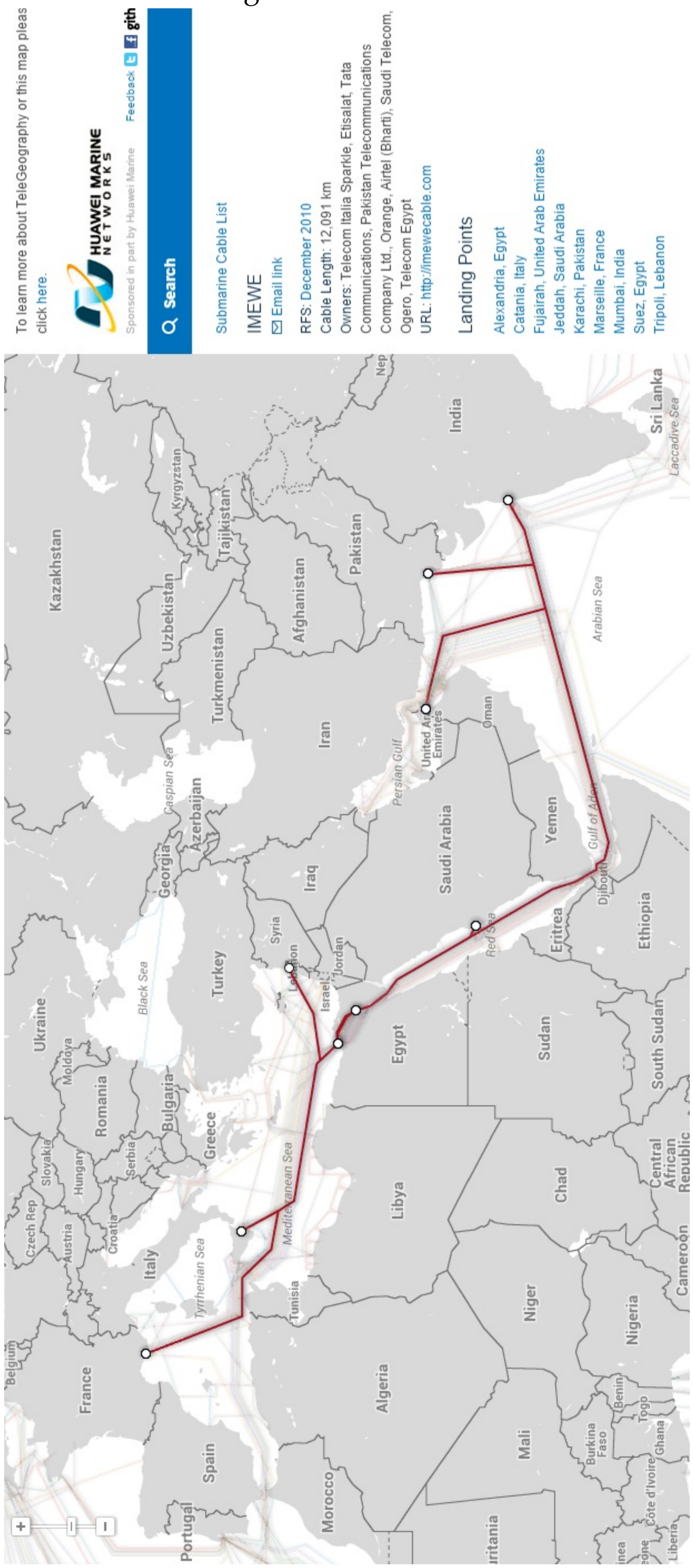


Table A4: Full Sample

	Cables (2-digit)	Tb/s (2-digit)	Cables (3-digit)	Tb/s (3-digit)
Data-Intensive Services	0.066	0.258***	0.127***	0.338***
	(0.044)	(0.103)	(0.048)	(0.119)
Other Services	0.034	0.100**	0.146***	0.377***
	(0.025)	(0.050)	(0.055)	(0.115)
Destination-Source-Sector FE	Y	Y	Y	Y
Source-Sector-Year FE	Y	Y	Y	Y
Destination-Sector-Year FE	Y	Y	Y	Y
Observations	683,997	683,997	669,919	669,919
Groups	41,828	41,828	41,825	41,825
R^2	0.880	0.880	0.878	0.878

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

Table A5: Restricted Sample

	Cables (2-digit)	Tb/s (2-digit)
Data-Intensive Services	0.414**	1.822***
	(0.208)	(0.653)
Other Services	-0.199	-0.289
	(0.151)	(0.708)
Destination-Source-Sector FE	Y	Y
Source-Sector-Year FE	Y	Y
Destination-Sector-Year FE	Y	Y
Observations	78,658	78,658
Groups	3,896	3,896
R^2	0.890	0.890

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

Table A6: Egypt Sample

	Cables (2-digit)	Tb/s (2-digit)
Data-Intensive Services	0.919***	2.249**
	(0.304)	(1.110)
Other Services	-0.370***	-1.288
	(0.095)	(0.791)
Destination-Source-Sector FE	Y	Y
Year FE	Y	Y
Observations	4,633	4,633
Groups	214	214
R^2	0.842	0.842

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

Table A7: Single Cable Connectivity

	Full Sample (2-digit)	Exo Sample (2-digit)	Egypt (2-digit)
Data-Intensive Services	0.174*	-0.076	0.628***
	(0.094)	(0.247)	(0.105)
Other Services	-0.053	0.136	-0.482**
	(0.053)	(0.284)	(0.195)
Destination-Source-Sector FE	Y	Y	Y
Source-Sector-Year FE	Y	Y	N
Destination-Sector-Year FE	Y	Y	N
Year FE	N	N	Y
Observations	683,997	78,658	4,633
Groups	41,828	3,896	214
R^2	0.880	0.890	0.842

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

Table A8: Inclusion of Quadratic Term

	Full Sample (2-digit)	Exo Group (2-digit)	Egypt (2-digit)
Gb/s, Data-Intensive Services	0.232	-18.940**	-87.251**
	(0.932)	(9.140)	(39.676)
Gb/s^2, Data-Intensive Services	-0.088	9.589**	43.796**
	(0.464)	(4.601)	(19.874)
Gb/s, Other Services	-0.034	14.800**	2.181
	(0.053)	(7.262)	(7.279)
Gb/s^2, Other Services	0.022	-7.445**	-1.158
	(0.266)	(3.671)	(3.650)
Destination-Source-Sector FE	Y	Y	Y
Source-Sector-Year FE	Y	Y	N
Destination-Sector-Year FE	Y	Y	N
Year FE	N	N	Y
Observations	683,997	78,658	4,633
Groups	41,828	3,896	214
R^2	0.880	0.890	0.843

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

Table A9: Poisson PML (Egypt)

	Cables (2-digit)	Tb/s (2-digit)
Data-Intensive Services	0.533***	1.157*
	(0.190)	(0.665)
Other Services	-0.271**	-0.834***
	(0.119)	(0.302)
Destination-Source-Sector FE	Y	Y
Year FE	Y	Y
Observations[a]	4,644	4,644
Groups[a]	217	217

Standard errors are clustered at the Destination-Source level. Asterisks represent statistical significance at the 10% level (*), 5% level (**), and 1% level (***).

[a]The glm command in Stata does not drop singleton observations. As such, there are 11 more observations and three more groups than in previous regressions with this sample.