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Accessibility of cities in the digital economy

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ABSTRACT

This paper introduces a new measure to approach the accessibility of places in the frame of the digital economy. Information and Communication Technologies (ICTs) and the Internet are not equally spread around places and this heterogeneity affects spatial configuration. Despite the wide societal changes due to ICTs and the extensive interest in accessibility studies, these two themes have not yet come together in order to study the digital accessibility (DA) of places. Adopting an infrastructural perspective and a potential accessibility framework, a DA measure – embedding different types of impedance distance functions – is calculated for cities in Europe. Spatial Interaction Model and Complex Network Analysis are employed to calibrate and validate the DA results. The outcome of this approach is a new urban hierarchy which reveals a core-periphery pattern in Europe owing to digital accessibility.

Introduction

This paper introduces a new concept for the accessibility of places in the frame of the *digital economy* based on a conventional potential accessibility measure. Starting in the late 1940s, scholars studied the way individuals and aggregates of individuals respond to the constraints of cost, time, and effort to access places, individuals, and other spatially-distributed opportunities (Couclelis, 2000; Couclelis & Getis, 2000). A common component of the various different accessibility concepts is the easiness to reach opportunities: while Hansen (1959) defines accessibility as the potential of opportunities for interaction, Morris, Dumble, and Wigan (1979) approach accessibility as the ease with which activities can be reached from a certain location; in a more general way, Couclelis (2000) reinforces the concept of accessibility as the geographic definition of opportunity, while Reggiani, Bucci, and Russo (2011a, 2011b) link it with spatial structure effects and notions such as network connectivity.

Regardless of the substantial literature on accessibility, research on accessibility has not yet incorporated questions related to the rapid increase in Information and Communication Technologies (ICTs). Exceptions include the rather conceptual, but also empirical, proposals found in the volume edited by Janelle and Hodge (1998) and the graph oriented approach by Wheeler and O'Kelly (1999). The novelty of this paper is the amalgamation of *opportunities* for virtual interaction and the *cost* to reach the opportunities in the digital economy. ICTs have impacted heavily on the spatial configuration, and led Castells (1996) to develop his ideas about this new spatial organization identified as the *space of flows*. ICTs affect spatial configuration as a result of their friction reducing character, and their ability to reduce the cost of distance (Cohen, Salomon, & Nijkamp, 2002; Cohen-Blankshtain & Nijkamp, 2004).

This lack of interest is not surprising, as it reflects the rather limited attention ICTs attract from the wider field of economic geography and spatial economics because of their technical and intangible nature. Indeed, both economic and urban geography usually deal with tangible objects, contrary to the elusive and complex technical nature of telecommunications, and specifically the Internet (Bakis, 1981; Hepworth, 1989; Kellerman, 1993). After all, telecommunications infrastructure only becomes visible when it stops working (Star, 1999). In addition, the lack of – freely accessible – relevant secondary data has also discouraged researchers in entering this research field.

However, there is scope for the above-mentioned disciplines to include research questions regarding the geographic effects of new technologies, and, consequently, the accessibility of places from a *digital* perspective: ICTs, in general, and the Internet, more specifically as the broader telecommunications platform, are not a unique system evenly scattered regardless of core or periphery (Gorman & Malecki, 2000). Geographic location affects the Internet connectivity and the speed at which data can be transmitted and received, because of the uneven spatial allocation of the Internet's physical infrastructure across space (Malecki & Moriset, 2008). This might not be visible from the end-user point of view, but, at an aggregated meso – metropolitan and regional – level, the allocation of the Internet infrastructure, such as vast and redundant international and local Internet links and peering locations, can affect the location advantage. The concentration of digital infrastructure in

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specific locations may influence the economic development of these areas, as it will provide better access to the digital economy, affecting the competitiveness at the micro- and the macro-level: through efficiency and effectiveness effects, Internet infrastructure can result in cost reduction and revenue increase for corporations; and through connectivity effects and the endowment of location factors it can impact the accessibility and the attractiveness of territories (Camagni & Capello, 2005). Put simply, the Internet infrastructure can both result in attracting new firms (Cornford & Gillespie, 1993) in a city which can exploit such infrastructure (financial firms, back-office activities, creative industries) and increase the productivity of existing firms. Additionally, such infrastructure might also result in higher quality digital services for end-users.

Our conceptual and empirical proposal of a digital accessibility (DA) measure builds upon the well-established parallel between transportation and ICT networks. On a first level, both perform infrastructural roles: the Internet transports the valuable weightless goods of the digital economy in the same way transportation networks transport the industrial goods (Moss & Townsend, 2000; O'Kelly & Grubesic, 2002). Similarly, while transportation infrastructure reduces the transaction costs on trade in goods, telecommunications infrastructure lowers the transaction costs of trading information and ideas (Cieślik & Kaniewska, 2004). However, the importance of knowledge creation needs to be highlighted here, which is related with personal interaction. The latter can be subdivided in two components: the conversation and the handshake, with the former being the metaphor for simultaneous real-time interactive visual and oral messages, and the latter representing the physical co-presence. ICTs can lower the cost of the conversation component (Leamer & Storper, 2001), but also facilitate physical spatial interaction. This discussion is reflected in the different types of relation between transport and ICTs identified in the literature (Banister & Stead, 2004; Cho & Mokhtarian, 2007; Mokhtarian, 1990, 2002; Salomon, 1986): substitution (reduction, elimination), complementarity (stimulation, generation), modification (change time, mode, destination, etc.), and neutrality (no impact of one medium on the other).

At a more technical level, both ICTs and transportation share topological similarities, as both are usually rolled out as spatial networks (e.g. Gorman & Malecki, 2002; O'Kelly & Grubesic, 2002; Wheeler & O'Kelly, 1999). Both consist of nodes and edges, and both of them can be analyzed using network techniques (Malecki & Gorman, 2001). Table 1 presents this analogy: the backbone links, which are the highest tier networks of the Internet physical infrastructure symbolize the motorways; the Internet Exchange Points (IXPs) and Points of Presence (POP), which are the points where different networks exchange data – a process known as peering – and final users gain access to the global network, represent the transport nodes (interchanges and access nodes); the Metropolitan Access Network (MAN) and the local loops symbolize the intra-city roads; and the Internet Protocol (IP) addresses denote the numerous final destinations in the cities – the Internet real estate according to Dodge and Shiode (2000).

Table 1
The parallel between the Internet physical infrastructure and the road infrastructure.

Importance at:	Internet infrastructure		Road infrastructure
Inter-city level	Backbone networks	↔	Motorways
	IXP/private peering points	↔	Interchanges
Intra-city level	POP	↔	Access nodes
	MAN/local loops	↔	Intra-city road networks
	IP addresses	↔	Premises

The above supports Couclelis and Getis's (2000) findings that recent technological and societal developments require the re-conceptualization of the notion of accessibility at all scales, as ICTs have radically changed and expanded the scope for notions such interaction and accessibility (Janelle & Hodge, 2000). More specifically, Dodge argues about the need to expand the notion of accessibility in order to include notions of information accessibility. Overall, ICTs have affected the three essential elements of accessibility (Dijst, 2004, p. 27): "the reference location from which access to destinations is determined; the set and attractiveness of opportunities; and travel impedance". From an empirical standpoint, it can be said that, while basic Internet access is available almost everywhere nowadays, the capacity of the installed infrastructure varies dramatically across different cities and regions, thus affecting the aggregated opportunities in these areas to participate and benefit from the digital economy. Given the above, the aim of this paper is to develop a city-level potential DA indicator based on the installed digital infrastructure. In other words, we will conceive here an analogy to transport network accessibility and potential opportunities, and estimate a compound value which takes into account the capacity of the digital infrastructure, as well as the cost of virtual communications.

The paper is structured as follows: next, Section 2 presents the conceptual and methodological framework and the relevant data; Section 3 illustrates the different DA measures. Then in Section 4 Complex Network Analysis (CNA) is employed to validate the results of the DA followed by the discussion of the results in Section 5. The paper ends in Section 6 with some concluding remarks and ideas for further research.

Conceptual and methodological framework and relevant data

The starting point of the DA measure lies in Hansen's (1959) seminal work, and, on the basis of this, we define DA as the *potential for virtual interactions*, which have the form of digital communications. At a generic level, the rich theoretical foundations and universal properties of the potential accessibility measures are well established in the literature (Reggiani, 1998). The basic formula for calculating DA has the form:

$$DA_i = \sum_j CP_j f(d_{ij}), \tag{1}$$

The DA_i is the digital accessibility interpreted as the aggregated potential opportunities for virtual interaction in the city i, while CP_j (cyberplace, following Batty's (1997) distinction between cyberplace and cyberspace) denotes the capacity of the installed digital infrastructure in city j. In more detail, CP indicates the total installed capacity for international intercity IP communications ($CP_i = \Sigma_j CP_j$). This type of digital infrastructure is responsible for the Internet's global character, as it connects remote destinations (Malecki, 2004). The installed capacity due to such networks in a city reflects the potential of the city to attract, generate, or route IP data flows. While the first two urban Internet functions (generation/attraction) are rather straightforward and share strong commonalities with traditional transport networks, the third (routing) is a characteristic of the Internet function. In a nutshell, a high capacity of installed infrastructure for international intercity IP communications reflects to a certain extent the localized demand for such communications – both attracting and generating communications. In addition, and because of the importance of routing in IP communications, the installed capacity at city level also reflects the nodal role that a city performs for IP data-flows routing at a global scale.

The data for the CP is derived from Telegeography (2009). Telegeography is a private consultancy firm, and nowadays is the only provider of such data at the global scale, and most of the