

Agglomeration in Internet Co-operation Peering Agreements

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Abstract

Peering decisions between Internet Service Providers contain substantial non-measurable aspects requiring trust and informal cooperation among peering partners. We study whether spatial agglomeration is observed between Internet peers. Our empirical analysis of the bilateral peering decisions at the Milan Internet Exchange confirms that these decisions are significantly influenced by: travel time between ISPs headquarters- a proxy for distance, bandwidth- a proxy for size, and European connectivity. Proximity still plays a role in reducing the transaction costs of monitoring and punishing deviant behavior within an industry where co-operation is essential for efficient traffic exchanges required by the Internet universal connectivity.

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Agglomeration in Internet Cooperative Peering Agreements

The MIX-IXP Case

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1. Introduction

Does geographical space plays a role in sustaining cooperation among Internet companies? While there is a growing literature on how Information and Communication Technologies (ICT) affect inter-firm relations, less attention has been paid on their effects on Internet Service Providers (ISPs), the firms which provide the interface between final users and the Internet. In this paper we investigate the possibility that geographical agglomeration of ISPs affects their propensity to peer at the Milan Internet Exchange (MIX). We start by considering the wider issue of the effects of ICT on geographical agglomeration forces and, in particular, on Industrial districts and we discuss how their governance requirements explain the significance of geographical proximity in the specific case study analyzed. We explore how ICT exert two opposite effects on agglomeration: a weakening of the centrifugal forces, due to the lessening of the isolation market power, and the redesigning of the barycenter of the centripetal forces, focussing agglomeration around virtual locations. This last possibility requires establishing conventions to facilitate the emergence of trust in cyber-mediated exchanges.

Our empirical analysis of the bilateral peering decisions of the ISPs connected with the MIX in Milan, confirms that these are significantly influenced by several

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explanatory variables: travel time between ISPs headquarters, bandwidth, and connectivity at other European Internet Exchange Points (IXP). Most importantly, we find that self-selected bilateral peering is significantly affected by geographical proximity. We believe this finding is linked to the role that proximity still plays in reducing the transaction costs of monitoring and punishing deviant behavior within an industry where co-operation is essential for efficient traffic exchanges required by the Internet universal connectivity.

1.1 Agglomeration

Spatial asymmetries, geographical agglomeration, industrial districts and their morphological changes in time are commanding a growing empirical and theoretical interest amongst economists. In one of the earliest contributions of this, renewed, debate Krugman (1991)¹ identifies concentration as "the most striking feature of the geography of economic activity". More recently Fujita and Thisse (2002) describe agglomeration as the interplay between two forces: *localised positive externalities*, that have a centripetal effect, and *transport costs*, that act as centrifugal force².

The *Industrial Organization* approach to space and agglomeration has been pioneered with Hotelling's "*Principle of minimum differentiation*" (1929). Assuming oligopolistic behavior, he argued that with linear transportation costs firms tend to locate at the center of a linear city and supply identical products. Agglomeration is the immediate result. D'Aspremont et al. (1979) assumed quadratic transport costs and reversed Hotelling's conclusion showing that firms tend to locate as far apart as possible from each other. This property has been called, the "*Principle of maximum differentiation*"³.

Irmen and Thisse (1998) however extended this modeling framework by considering firms' location decision in a *multidimensional characteristic* product space. They found that, in equilibrium, there is maximum differentiation along the most relevant characteristic and agglomeration along all others. Urban and economic history can be

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¹ For a critical assessment, from an economic geographer point of view, on how mainstream Economics "rediscovered" the spatial dimension along Krugman's work, see Martin (1999) and Martin (2003).

² Other centrifugal forces consist in local diseconomies such as congestion, land rents and commuting costs, or occur whenever factors of production are immobile.

³ Osborne and Pitchick (1987) proved the existence of equilibrium in mixed strategies where, unlike Hotelling's result, location decisions are not concentrated in the same place.

re-read along similar lines: before the industrial revolution high transport costs outweighed the comparably low fixed costs of production, hence production was fragmented into many small units. After the industrial revolution transport costs decreased dramatically, thus providing an incentive to agglomerate at few spatial locations⁴ and focus on product differentiation to retain market power. Krugman (1991) explained these dynamics of geographical agglomeration as the interplay of increasing returns, labour migration and transport costs⁵. Since Marshall (1920), agglomeration has been attributed to three forces: a pooled labour market, greater provision of non traded inputs, and knowledge spillovers. Glaeser, Kallal, Scheinkman and Schleifer (1992) stressed the importance of geographic proximity in defining the extent of knowledge spillovers within firms of a given industry to explain the agglomeration in cities⁶. Proximity matters since a basic input for firms' activities, *tacit knowledge*, is assumed to be only transferable through face to face interaction: "the transfer of information through modern transmission devices requires its organization according to some pre-specified patterns, and only formal information can be codified in this way" (Fujita and Thisse, 2002, p. 172). This assumption is often accepted without criticism, but how tenable is it? We think it has been overemphasized; images on a web-cam are transmitted through a codified protocol, not necessarily understood by the viewers, but nonetheless they convey tacit messages to them. Every image, sound, and written text, can be transmitted and reacted upon in real time: watching the Gioconda's smile on the Internet⁷ does transmit, through a codified sequence of binary numbers, tacit ideas. Following the widespread use of the Internet, geographical proximity may matter less than connectivity or language affinity. Hence, proximity, in geographical space, should be considered as a parameter reflecting the degree of transmissibility of the knowledge relevant to the specific

⁴ Note that this development hinges on the fact that there are increasing returns to scale. Otherwise there would be no incentive to agglomerate unless externalities play a role.

⁵ Krugman and Venables (1995) find an emerging "U-shaped pattern of global economic change, of divergence followed by convergence" by linking the changing patterns of the core-periphery relation to different stages of a process of gradually declining transportation and communication costs. Puga (1999) and Giovannetti (2000) also obtained a non-monotonic relation between transport costs and agglomeration.

⁶ Localized knowledge spillovers within endogenous growth models are sufficient to generate different growth rates between geographically separated locations. In this framework, asymmetry is not driven by agglomeration of production in space, but by quality differentiation across a fixed geographical setting.

⁷ Leonardo Da Vinci (1503-1505) *La Gioconda*, Oil on wood, 77 x 53 cm (30 x 20 7/8 in); Musee du Louvre, Paris See the WebMuseum (2002): <http://www.ibiblio.org/wm/paint/auth/vinci/joconde/joconde.jpg>

activity under study. This will differ across industries, according to their productive and organization features, and will reflect the evolution of the new technologies and their human-machine interface.

1.2 Our Paper

The paper is organized as follows: section 2 introduces the debate on the effects of ICT on the relevant notion of *distance*, either related to geographical or virtual dimensions. Section 3 discusses the role of trust and reputation in situations characterized by repeated incomplete contracts, as it happens in industrial districts. Section 4 provides a brief description of the main forms of interconnection in the Internet, while section 5 focuses on the nature of peering agreements. Section 6 discusses the rationale for observing agglomeration in the peering decision and Section 7 presents the econometric analysis of the Milan Internet Exchange peering matrix. Finally section 8 contains the conclusions.

2. Proximity in Cyberspace: Death of the Distance?

In some sectors, in particular for digital goods, new technologies reduce transport costs to almost zero, hence reducing the profitability for local market power and thereby weakening centrifugal forces. This leads to claims of “*death of distance*” whereby instantaneous communication made possible by the Internet leads to a collapse in space-time boundaries. Mitchell⁸ (1998) defines this as the economy of presence rather than proximity, and analyzes the implications on the comparative advantages of different locations which, more than on proximity, will be based on the idea of connectivity⁹.

Critical viewers of the space-less economy often stress the unique relevance of *face to face* relations, direct human interaction, which independently on the non direct human communication speed and cost characterizes the idea of *place* as different from *space*. Following this view a *place* has “insiderness”, i.e. it provides identification for the individuals belonging to it (Relph 1976, *Place and Placeness* from Dodge and Kitchin, 2000). Insiderness reintroduces distance between places which might have

⁸ As reported in Dodge and Kitchin (2000).

⁹ Kitchin (1998) argues that geography instead of becoming irrelevant is transformed, in particular since there is unequal spatial distribution of bandwidth and the underlying physical network topologies, so that the analysis of the geographic distribution of the information infrastructure becomes essential to understand the agglomeration forces.

distance-less communication costs. However this does not necessarily link a place to a specific geographical location: insidership of an online community will in fact define borders but these are not drawn in geographic space¹⁰.

The trade-off between centripetal and centrifugal forces, defining agglomeration and districts' boundaries, is therefore not only affected by the impact of new technologies on the costs-relevance of distance, but also depends on whether these facilitate the emergence of *cyber-places* characterized by local externalities only reaching *peers*. Summing up, technology might then have two opposite effects on the agglomeration process: one weakening the centrifugal forces, due to lower transport costs; and the other facilitating agglomeration around *virtual locations*.

Usually the nature and range of local externalities is closely linked to the language and protocol used for communicating. Online communities¹¹ generated their own language protocols and expressions that are delimiting borders of traditional languages for reciprocal understanding. Fluency in this format is however only very loosely connected to geographical location. To replace geographically defined districts, these virtual districts have to develop the ability to establish, maintain and verify *reputation* and *trust*. This possibility is itself linked to the evolution and diffusion of both: a) Public Key Infrastructure encryption technologies¹², such as Digital Signature and Certificate and b) the power of enforcement of legally binding cyber-agreements¹³. However, although being necessary conditions, encryption technologies and a clear legal enforcement framework do not provide a sufficient condition for the establishing of *trust* in cyber-mediated relations because, at least, of contract incompleteness. The inability of drafting complete contracts is often dealt through the emergence of *conventions* both in geographical and cyber space interactions. Hence the relevant issue in understanding the possible emergence of *virtual districts* becomes: "do new technologies provide the means for the emergence of conventions necessary to facilitate trust in cyber mediated exchanges?"

¹⁰ Places in cyberspace are formed by a common interest affinity and language more than geographical proximity. It has been argued that moral commitment and social cohesion are primary identifiers of places in cyberspace and that places emerge as a consequence of the relationships that the subjects participating into them establish among themselves.

¹¹ Relevant examples are provided by Weblogs which often allow visitors to leave public comments, which can lead to a community of readers centered around the Blog. The totality of weblogs or blog-related websites is usually called the Blogosphere.(Wikipedia)

¹² See Maeda (2002).

¹³ Which is of course linked to evolution of the transnational legal agreements concerning the electronic communication sector.

Online *places* have been historically characterized by behavioral codes also called *netiquette*, the breaking of which has often disruptive consequences on the deviant's reputation within the community. If there is competition between geographical and virtual districts, their relative competitive advantage will depend on whether the monitoring of these codes is easier through geographical proximity or via online interaction, and if the ensuing necessity of a credible retaliation of a deviant's behavior is more easily implemented within an online connected community or in a geographically clustered one.

These elements taken together should drive the agglomeration/ polarization dynamics in the specific industry under study, defining the shape and borders, if existing, of the geographical or cybergeographical distribution of the industry.

3. “Relational Governance” as a centripetal force for districts

The issue of the survival of geographical agglomeration when ICT becomes an efficient substitute of face-to-face dealings has been addressed by Santarelli (2004). In a panel data analysis of the long term evolution of Emilia Romagna's industrial districts, he found that spatial concentration is no longer the most crucial factor in agglomeration and the term “multi-located”¹⁴ district describes recent forms of industrial agglomeration in a better way.

A crucial feature of industrial districts is their microstructure: small firms; vertically disintegrated production (vertical specialization); a flexible system of vertical and horizontal subcontracting. These features were already noticed by Marshall (1890), and have been stressed more recently by Brusco (1982) and Becattini (1989). What hasn't perhaps been sufficiently stressed is that a vertically fragmented industry relying on frequent vertical and horizontal subcontracting implies a large number of transactions which are likely to require a good governance system, which may require a certain degree of spatial concentration. Williamson (1996) distinguishes three main forms of governance for inter-firm (vertical and horizontal) transactions: explicit contracts, assets posted as hostages, and relational (or implicit) contracts. Assets posted as hostages are seldom observed and “complete” explicit contracting is seldom a feasible option for firms in a district because court enforcement involves fixed costs and is not economic for small transactions between small firms. Therefore transactions within districts must be mainly governed by long-term relations, where

¹⁴ For the origin of the term see also Santarelli (1988).

reputation forces can ensure compliance with exchange agreements (preventing “hold-up”; see Blonski and Spagnolo, 2002). Brusco and Beccattini stress that interaction within a district involves forms of inter-firm cooperation. Recent observers focused on “cooperative information sharing” among competing firms in R&D-intensive industrial districts. For example Saxenian (1994) discusses how informal, cooperative social relations play a crucial role in enforcing knowledge exchanges within the computer-industry district in Silicon Valley. For the biotechnology industry, Powell (1996) and Powell et al. (1996) argue that formal arrangements merely represent the tip of the iceberg, "beneath which lies a sea of informal relations", and point out that the "development of cooperative routines goes beyond simply learning how to maintain a large number of ties". But information sharing apart, *all transactions* between small firms in a district (any vertical and horizontal subcontracting) require a form of cooperation, of “relational governance” and sufficiently strong reputation forces.

However the effectiveness of reputation forces may be enhanced by having transactions embedded in a community, in a social network, since this may facilitate information transmission (Kandori, 1992). A district embedded in a community network, with its tissue of social relations, may also rely on social sanctions - besides usual economic ones – as additional threats to discipline and govern inter-firm transactions (Spagnolo 1999, 2000; Annen 2001). Retaliation against deviants can take place in both social and business life, increasing incentives to behave. This form of “social capital governance” is common in many districts around the world, and may constitute a substantial comparative advantage for agglomerated, embedded districts.

Recent experiments on “cheap talk” in coordination and repeated games provide an additional ground to believe that the need for effective relational governance may constitute a significant, as yet disregarded centripetal force for districts. Pre-play communication in game-theoretic experiments, “cheap-talk”, can be seen as a special form of “face to face” interaction¹⁵. However, the value of this kind of face to face communication does not lie in a more direct and precise transmission of information – as usually argued in the agglomeration literature – since experiments are expressly

¹⁵ Brosig et al. (2003) test experimentally in a standard public good game the effect of different communication media on cooperation. They find that cooperation is the highest and the most stable when participants were allowed to communicate both verbally and visually. Obviously, it is crucial for

designed so that *cheap talk conveys no information whatsoever* (see Crawford, 1998). Rather, this form of face to face interaction has been shown to have value in facilitating agents' coordination and the creation and maintenance of *trust*, an essential ingredient of the long-term cooperative relations necessary to govern at low cost a complex, flexible system of subcontracting.

To wrap up, this section identified a novel potential centripetal force based on the governance needs of fragmented industrial districts. Reputation forces are important for the cost-effective governance of small transactions and flexible informal subcontracting. Agglomeration may or may not help in terms of better information flows since, as argued in previous sections, ICTs may soon effectively substitute for face to face and community-managed information transmission. But geographical closeness may help the reputational governance of districts' subcontracting systems by allowing for community embeddedness – hence for social sanctioning power to enforce exchanges – and for better trust building thanks to personal, face to face interaction.

Note that this force will be important where explicit contracts and the court system are relatively expensive, but also when crucial aspects of inter-firm transactions are not easily monitorable and verifiable, in which case formal contracting is impossible even where the court system is efficient. Robust experimental evidence indicates that the presence of important non-contractible aspects in a transaction immediately lead to abandoning spot markets and establishing long-term cooperative relations (Fehr et al. 2001). As discussed below, in the peering decision between ISPs there are substantial aspects of the transaction that are impossible to measure or monitor, so that the peering decision may require substantial trust and informal cooperation between peering partners. This may activate the centripetal force discussed above: face to face meetings and social connections may facilitate the governance of peering agreements, and the former may benefit from geographical proximity.

4 The Internet

The Internet is composed of many independent networks of very different sizes, located around the globe, all directly or indirectly interconnected with each other. This last feature guarantees the Internet's most important property: universal

the establishment of trust to see and observe your counterparts. Whether this face-to-face

exchange of traffic between all end users (universal connectivity). The industry is still rather unregulated, and networks are left completely free to decide where, how and with whom to interconnect. Lacking a really dominant network, competitive forces and positive network externalities have been sufficient until now to keep all the networks interconnected¹⁶.

Small Internet Service Providers (ISPs) rely on connections to larger networks for the delivery of their customers' data packets to their destinations outside the range of the ISP's own subscribers. The largest networks are called Backbones. These own or lease national or international high-speed fiber optic networks and deliver packets around the world for the many smaller networks connected to them. Backbones may also reach businesses and consumers directly by operating own vertically integrated¹⁷ ISPs.

4.1 Interconnection Agreements.

Two simple types of interconnection agreements have emerged to regulate traffic at exchange points between networks: transit agreements and peering agreements.

In a *transit agreement*, a large network – the transit provider - offers access to the entire Internet to a smaller customer network against the payment of a fee often related to the capacity of the connection link¹⁸.

Under a *peering agreement* two networks exchange the traffic directed to each other's end users only. Monetary settlements between peering partners used to be excluded, although recently some networks have started charging for peering (Miller 2002). Peering can be seen as a reciprocal, non-monetary exchange relationship that often implies various forms of cooperation. Peering also implies establishing direct exchange points between the two networks, and the costs of creating and maintaining the exchange points are typically shared evenly. Peering agreements may also be multilateral, and traffic exchanges may take place at organized exchange points such as Network Access Points (NAP) and Internet Exchange Points (IXP), specialized facilities where ISPs can connect to each other to exchange Internet traffic. To peer at

communication took place in one room or via video-conference did not seem to matter.

¹⁶ Were a really dominant network were to emerge, network externalities may become a problem, and the dominant network could then have interest to refuse interconnection to other networks in order to drive them out of the market. This would destroy universal connectivity, a potential event sometimes referred to as the "balkanization" of the Internet that would require regulatory intervention (Kende 2000).

¹⁷ For an Analysis of the Incentives towards vertical integration for Internet backbones, see Giovannetti (2005a).

a NAP/IXP an ISP usually has to establish a connection and pay a membership fee, after which it can use the circuit to carry the aggregate traffic to all of the other members of the NAP/IXP with whom the ISP agree to peer. This makes peering at a NAP/IXP cheaper than establishing a direct bilateral peering exchange point which would require installing a direct connection and many commercial deals.

Being a member of a NAP/IXP offers further advantages like sharing information and a free mutual technical help forum.

4.2 Technological aspects.

Three important technological features of the Internet frame the subsequent discussion: first, only the amount of traffic exchanged between two networks can be measured, and not the paths followed by each packet within the network.

The second feature is the “Hot Potato Routing”: when two networks are connected at several exchange points, each network routes all traffic as soon as possible into the other network. This individually optimized routing principle is inefficient since the traffic does not necessarily follow shorter or uncongested paths.

The third feature is that the speed of the connection between two end users is crucially determined by the degree of congestion in the various networks the traffic crosses. The most congested network on the path determines most of the delay.

5. The Peering Decision

Earlier work has identified several factors and problems that may affect networks’ decision whether and with whom to peer¹⁹. A first, rather obvious factor is size.

5.1 Peering and Size

Peering requires establishing bilateral traffic exchange points, or peering points, which entail fixed and variable technological costs. It follows that a sufficiently intense traffic flow between the end users of the two networks is a necessary precondition for peering to be economically viable. The larger two networks are, the more intense will be the traffic between their end users, and therefore networks’ size is a determinant of the peering decision.

¹⁸ For an analysis of the competitiveness of the transit market see Giovannetti and Ristuccia (2005b).

¹⁹ See Huston 1999; Baake and Wichmann 1999; Kende 2000; and Filstrup 2001.

In fact, almost all large backbone networks peer with each other, the traffic being exchanged at several interconnection points homogeneously distributed on the relevant geographical areas. Somewhat smaller networks also peer with networks of comparable size, but typically have to supplement their interconnection with transit agreements with backbone networks.

5.2 Peering and Symmetry

Since the costs of setting up and maintaining peering points are usually shared equally by peering networks, unbalanced traffic implies an unbalanced distribution of gains from peering against a balanced distribution of costs, a rather unfair settlement. Such unbalanced situations have developed in some cases, and have led to the discontinuation of the peering arrangement and to its replacement with a transit one²⁰.

5.3 Avoiding Free Riding

When two networks are peering and one of them is congested, the perceived speed of connection would not improve were the non congested network to upgrade its infrastructure. And if the congested network chooses not to upgrade its infrastructure, it enjoys the full cost savings while it shares the reduced performance with all the networks it is peering with. This problem may of course induce caution in networks' decision whether and with whom to peer. Avoiding the race to the bottom this free-rider problem may induce can require active cooperation on the side of peering networks.

6. Agglomeration in Peering?

Little is known about the potential effects of ISPs' geographical location on their peering decision, the focus of our empirical analysis. Should we expect the geographical location of different ISPs to influence their decision whether to peer? Of course, if two ISPs are very far away building a connection from scratch would be very costly; hence one would expect that very far ISPs would not peer. However,

²⁰Recently, large networks started publishing guidelines for peering partners. WorldCom, in particular, published four criteria to agree to peering with a network, two of which being that the peering network has a geographic scope of at least 50% of its own; and that the traffic flow at peering points does not exceed 1:1.5. Asymmetric flows and geographical extension, together with the "hot potato routing" would place on the larger network a relatively larger burden in terms of traffic carried and relatively smaller gains. The lack of monitoring technology makes monetary compensation for these asymmetries hard to agree upon. The other two conditions required by WorldCom from peering partners are that the

consider a situation where there is an IXP where peering is cheaper, and that there is a number of ISPs all of which are connected to this IXP. Should we then expect the geographical location of these ISPs to matter in their choice of peering partners? Should agglomeration patterns be observed in the peering decision?

The centrifugal force discussed before, softening competition through local differentiation, would not be active in this case, since the decision to peer at the IXP is independent from the location choice of the ISPs with respect to end users²¹.

Some centripetal forces considered in the literature, such as knowledge spillovers obtained through interactions with peers, may be moderately active; and transport costs would be represented by the mile-cost of interconnection and the cost of reaching peers for joint activities and face to face interaction. Though, since we consider a population of ISPs all of whom *are already connected to a given IXP*, mile-cost of interconnection does not matter.

As discussed above, many features of a peering agreement are not directly monitorable, not to say verifiable/contractible. Hence peering agreements may require a great deal of trust and informal cooperation, in which case “face to face” can be important.

In the next section we perform an empirical analysis of the factors affecting the likelihood of bilateral peering for the population of ISPs connected at the Milan Internet Exchange, to evaluate the strength of agglomerating forces on the peering decision.

7. Empirical analysis

Italy has three major public Internet Exchange Points: two located in the Northwest: the MIX in Milan and the TOPIX in Piedmont and one in central Italy: the Namex located in Rome. While the MIX (67 members) and the NAMEX, (16 Members) have academic origins the TOPIX, (15 members) has been launched, in 2002, by a consortium of network-operators. Our empirical investigation focuses on the MIX²², whose statutory aim is to facilitate the cooperation and communication between ISPs in Italy. Access to the MIX is open to any operator upon acceptance of the conditions

volume of traffic exchanged at peering points is sufficiently large (>150 Mbps), a size criteria whose rational was discussed above; and that that most of the peering network has a capacity of 622 Mbps.

²¹ It is indeed a decision for the upstream connectivity, and not about downstream retail market.

²² The MIX S.r.l. (Ltd) was founded in January 2000.

included in its *Memorandum of Understanding*²³ and these reflect elements of non-profit, co-operative, behavioral patterns whose relevance to the peering decision has been discussed above. In particular bilateral peering agreements established within MIX premises must be free of charge and each member must ensure that its usage of the MIX resources is not detrimental to the usage by other members.

On the other side the MIX s.r.l. will adhere to the commitments to publish and update, to the sole benefit of the members: the peering matrix; the bandwidth for the reference period; the traffic statistics for the reference period; the quality of the offered service for the reference period and to provide support to the members in the set-up procedures of their equipment²⁴.

7.1 The Data.

The data are taken from the MIX peering matrix, which provides details of the actual choice of binary peering among its members and their nominal bandwidth at the MIX. We measured geographical distance based on the driving time between the headquarters of each ISP using the Driving Directions of the Yahoo! Maps web site. We finally searched for each member of the MIX whether it was participating at other European Internet Exchange Points, by looking at their peering matrices. The number of additional IXP's any ISP was a member of has been used as a proxy for its level of European connectivity.

7.2 Descriptive Analysis of the MIX Peering Matrix

To explore the possibility of *peering status* asymmetries among the ISPs composing the MIX membership, we start by looking at the absolute distribution of peering agreements. This allows us to explore whether there is multi-modality, potentially expressing clustering.

A simple look at Figure 1 below, displaying the absolute frequencies of existing peering agreements shows that the modal peering frequency, at the MIX is very high,

²³ See the web page at <http://www.mix-it.net/Documenti/regolamento-en.htm>

²⁴ Each ISP joining the Exchange will pay : 7746,85 Euro “una tantum”, representing the joining fee for 10 years; this cost will represent the penalty fee in case of disjoining from the MIX S.r.L. before the end of the 10 years and an annual membership fee based on the nominal value of the bandwidth (the bandwidth the ISP uses on the MIX LAN) that each ISP has declared. These fees are not including: the costs for connecting the ISPs site to their equipment within the MIX and the configuration of ISPs equipment within the MIX. Source : MIX S.r.l. MoU.

just above 50, displaying a large majority of well connected ISPs, with a small subset of ISPs having very few agreements only.

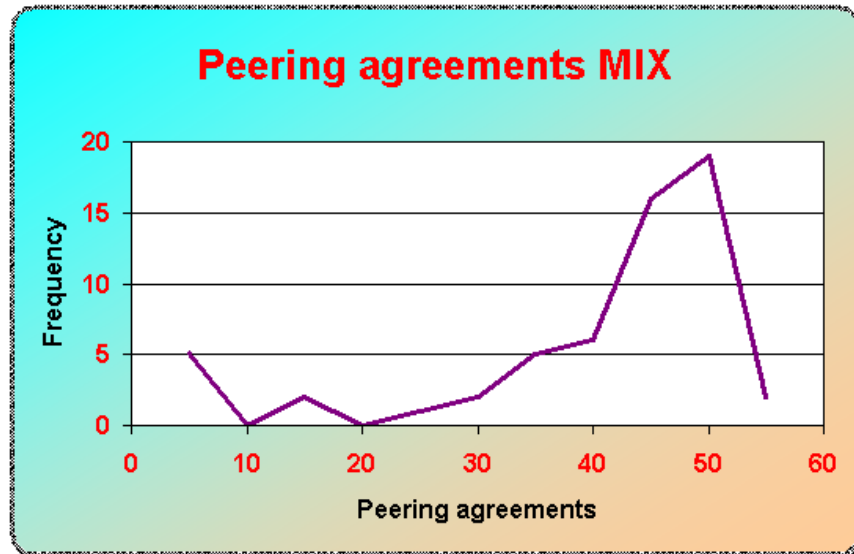


Figure 1: Absolute distribution of peering agreements at MIX

By looking at the *peering connectivity index*, i.e. the ratio of effective peering agreements over potential number ($N \times N - 1$) of them, we can see how well the exchange resources are utilized by its members²⁵. The index value of 0.67, obtained from the peering matrix, shows that the MIX reached high connectivity.

7.3 The Probit Models

Information about global connectivity and inequality within an IXP can be also drawn by looking directly at patterns emerging from the peering matrix.

²⁵ This index expresses how *meshed* the MIX network is.

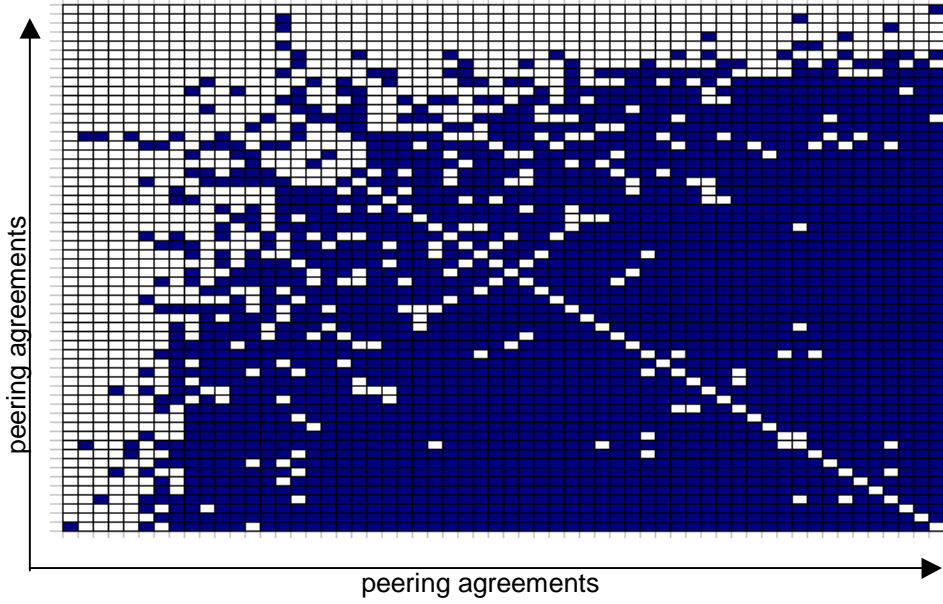


Figure 2: MIX Peering matrix sorted by number of peering agreements

In particular Figure 2 above gives the peering matrix of the Milan IXP as of 11/2002. We sorted the ISPs according to their number of existing peering agreements²⁶. Two thirds of all pairs have signed peering agreements, as seen in the connectivity index before; this is mirrored in the dominant dark color of the patterns of Figure 2.

In the following we introduce an econometric model with the aim to characterize the determinants of the peering decisions of ISPs at the MIX. As the nature of peering decisions is binary, we introduced a Probit model, in which explanatory variables define the likelihood of a peering agreement being signed. In particular, we considered four regressors: Travel time between headquarters (A), Maximum travel time towards MIX (B), Maximum bandwidth (C) and total number of connections at other European IXPs (D).²⁷

The general expression for the model is given by

$$\Phi^{-1}(p_i) = \beta_0 + \beta_{1i}A_i + \beta_{2i}B_i + \beta_{3i}C_i + \beta_{4i}D_i \quad i = 1, \dots, n$$

where Φ^{-1} is the inverse standard normal cumulative function.

We estimated three models, considering different subsets of explanatory variables. Table 1, below gives the estimated coefficients and confidence intervals obtained.

²⁶ A dark cell indicates a peering agreement between the two ISPs individuated by the cell's row and column.

²⁷ To facilitate the interpretation of the results all distances and bandwidths have been normalized such that their maximum value is one. The similar size of all coefficients indicates that all explanatory variables represent a significant effect.

VARIABLES	VARIABLES	COEFFICIENTS (MODEL WITH THREE VARIABLES: S: A,B,D)	COEFFICIENTS (MODEL WITH THREE VARIABLES: S: A,C,D)	COEFFICIENTS (MODEL WITH INDIVIDUAL VARIABLES)
A: Travel time between HQ	[0,1]	-1.20±0.13		-1.59±0.13
B: Max travel time to XP	[0,1]		-1.28±0.14	-1.63±0.13
C: Maximum bandwidth	[0,1]	0.89±0.12	0.92±0.12	0.61±0.11
D: Total number of connections at other European IXPs	[0,17]	-0.15±0.01	-0.15±0.01	-0.17±0.10

Table 1: Value of coefficients corresponding to explanatory variables with standard error.

7.4 Discussion

The negative²⁸ coefficient for travel time between the headquarters of the ISP companies, variable (A) indicates, that the companies are less likely to peer, the larger the distance between the headquarters. On the other hand, companies are more likely to peer, the bigger the bandwidth of the larger company, as expressed by the positive coefficient of variable (C), showing that the more traffic they have the more justified is the effort required to sign a peering agreement. Finally, companies are less likely to peer the more other IXPs in Europe they are members of, as expressed by the negative sign in front of variable (D). This is because ISPs can presumably exchange traffic at other locations. Finally in order to compare the different models we consider the increase in predictive power they produce under different combinations of explanatory variables. Figure 3 below shows the log-likelihood of

the observed peering behavior. The highest predictive power of our model is achieved with the combination (A,C,D). The relative increase in log-likelihood over the other variable combinations is represented by a lower negative log-likelihood²⁹ value.

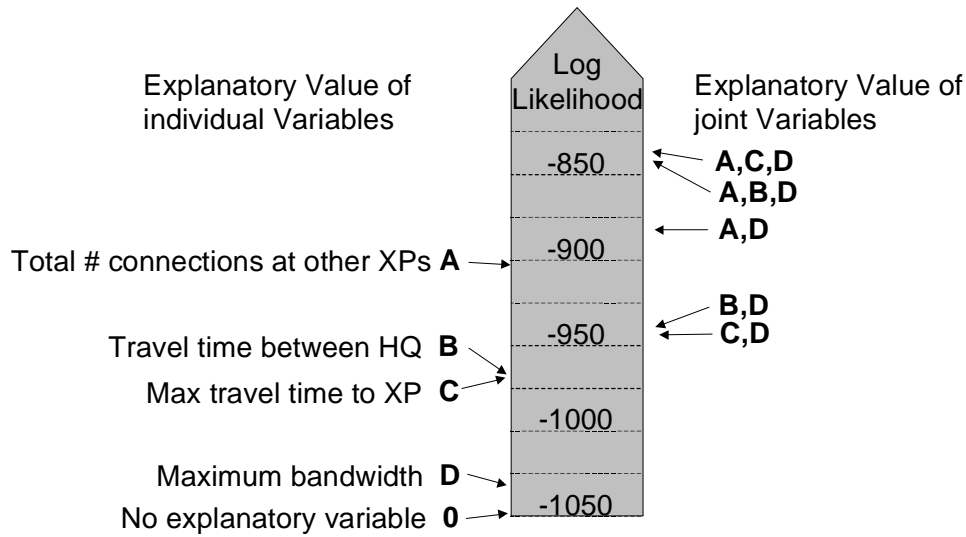


Figure 3 Relevant Explanatory Variables (Probit Estimation)

The *hit rate* is a heuristic illustration of the total predictive power of the model. Given that 66% of ISP pairs do peer at the MIX, an uninformed person judging on the basis of the connectivity index only, would predict for each pair to peer and therefore predict successfully in 66% of the cases. By using additional information, on travel distance and connectivity, as incorporated in the model using the three explanatory variables **A,B,D**, one is able to improve on this peering prediction and succeeds in 76% of the cases, having articulated the prediction not on the basis of random guessing, but on informed elements characterizing the pair of ISP under scrutiny.

²⁸ It is reassuring that the value coefficients if only one explanatory variable is used in the estimation do not change when additional explanatory variables are added. Otherwise we might assume e.g. a (negative) correlation between the 'explanatory' variable and the real, causal effect.

²⁹ In the estimation we first used the travel time between the headquarters of the ISP, and could identify a significant effect. The closer the headquarters are together, the more likely they will sign a peering agreement. However, in a second approach, we run a regression with the maximum travel time of either ISP to the Milan IXP and obtain similar results. This is because both explanatory variables are highly correlated (Correlation 0.982). The estimation does therefore not allow to judge, whether vicinity of headquarters is the decisive element, or whether vicinity of all parties to the IXP is more important for the signing of a peering agreement.

8 Conclusions

In this paper we investigated the possibility of geographical agglomeration in the bilateral peering decisions of Internet Service Providers participating to the Milan Internet Exchange Point. We considered the wider issue of the effects of the Information and Communication Technologies on geographical agglomeration forces and, in particular, on Industrial districts and we found that their governance requirements explain the significance of geographical proximity in the specific case study analyzed.

We discussed how ICT exerts two opposite effects on the agglomeration: a weakening of the centrifugal forces, and a redesigning of the barycenter of the centripetal ones, focussing agglomeration around virtual locations. Peering decisions between ISPs contain substantial non-measurable aspects requiring trust and informal cooperation between peering partners. Our empirical analysis of the bilateral peering decision of the ISPs connected with the MIX in Milan, confirms that the peering decision is significantly influenced by several explanatory variables: travel time between ISPs headquarters, bandwidth, and European IXP connectivity. IXPs are still playing a crucial role in fostering the emergence of virtual ISPs communities; self-selected bilateral peering is significantly affected by geographical proximity, drawing physical borders across the cyber-place provided by the IXP. We believe that this is due to the role that proximity still plays in reducing the transaction costs of monitoring and punishing deviant behavior within an industry where co-operation is essential for efficient traffic exchanges required by the Internet universal connectivity. This consideration is due to a new effect, different from those previously identified in the literature, agglomerated districts should have better governance – i.e. lower transaction costs -- than more dispersed ones. Therefore agglomeration facilitates cooperation that is not covered by contractual arrangements.

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