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Internet as a critical infrastructure: lessons from the backbone experience in South America

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Abstract: The radical transformations that have been reshaping the world of telecommunications are uniquely decentralized and, yet, they increasingly provide the lifeblood of our new societies. In this paper we study the internet as a critical infrastructure whose efficiency depends upon the proper and efficient functioning of its market structure. Our objective is not to propose the role governments should play. It is not to suggest regulation. It is exclusively to highlight the vulnerability of the economy to the lack of competition and associated problems due to inefficient market structures. The analysis in this paper is buttressed by the unique in-depth empirical research one of the authors has already carried out on internet in South America, covering many of its national idiosyncrasies, and its various forms of governance. South America is particularly interesting in view of the different ways in which networks came to interconnect with one another and

the diversity of governance one finds at points of internet traffic exchange. This subject will form the basis for further work.

Key words: Internet, critical infrastructure, externalities, regulation, NAP (network access point), peering, transit, governance, South America

1. Introduction

Internet is now an essential element of most economic activities around the world. In this paper we contend that it is now a "critical infrastructure". No region, no country and no economy can afford to overlook the internet without finding itself just as isolated from the world economic activities as a region without access to adequate shipping and railroad transportation would have found itself a century ago.

The internet is unique among infrastructures. Apart from its original creation, it has grown largely free from government intervention. Some (Economides 2004) argue that it is competitive and that government intervention would do more harm that good. This analysis, while interesting, is somewhat self-fulfilling; as Economides tends to see the internet environment as inherently competitive, his conclusion that competition makes regulation and other forms of government intervention unnecessary is largely predictable. Regardless, these conclusions do not seem to conflict significantly with a superficial look at the issue. Laffont et al., through a series of papers (especially 2000 and 2003), came to different conclusions. However, both were looking just at a specific problem, namely, whether the merger of MCI with Sprint might harm competition at the backbone level.

Just to explain our argument through an exercice of issue confrontations, we can state that Economides and Laffont et al. are looking at a very different question from the one we study here. They look at the internet as a common sector in the economy and evaluate its level of competitiveness. They do not take into account the unique role infrastructures continue to play in the proper functioning of the economy, i.e., the kind of policies that might protect the economy from market-based infrastructure crisis.

In this way the object of this work is not to be a generic paper on infrastructure. It is only to establish that the internet is indeed an infrastructure, to identify what are the elements of the internet that together form its infrastructure. Most of the internet has nothing to do with infrastructures. It is a huge bazaar where one can find all kinds of information, from an online video game such as *The World of Warcraft* to most of the scientific studies that have been produced to evaluate new medications.

This paper aims to provide a better understanding of the nature of internet infrastructure, i.e., what is it that is critical in the internet. We do not expect to reach some simple answer because the internet is (or has become) too complex an entity. It would seem useful to look at the question from both a bottom-up and top-down perspective. In addition, the internet is multidimensional, involving dimensions such as hardware connections, software connections and security. Somewhat like in a human body, these connections coexist and rely on each other's organization or governance. While each relies on the others, each is its own infrastructure in itself.

The *sine qua non* to running an internet is the IP layer and everything below this layer that sustains it. The services above it, including security, are important, but they are value-added services that make the internet more valuable to more stakeholders. The internet could function without them.

Below the IP layers are the telecommunications layers. Since the time of Vail in the early 1900s they have been presented by operators as a non-separable whole and, following the technology choices made by vertically integrated entities, they have become non-separable to some extent (Temin, 1987; pp. 18 and 74). There is some truth in the problems faced by incumbents with unbundling, not so much because it is naturally efficient to have all those functions vertically integrated, but rather because, for almost a century, operators did not have to be concerned by the issue and its efficiency. However, it is also clear that lack of separability has everything to do with sustaining a de facto monopoly and probably nothing to do with efficiency (Fontenay, Liebenau, and Savin 2005; Fontenay and Hogendorn 2005). The question becomes whether or not the layers below the IP layer are to be treated as an indivisible whole and the answer is rather trivial, since vertical integration is due to path dependence initiated in the early 1900s by Vail, rather than through efficiency. In addition, a look at sub-elements, such as cables or poles, immediately reveals that there is nothing making integration efficient.

It follows, as shown in Fontenay et al. (2005), that there is no reason to treat the complete set of activities below the IP layer as a monolithic monopoly infrastructure and that doing so is inefficient. If the backbone sector, i.e., everything below the IP layer, was contestable, then vertical integration would not have any effect on competition and governments would have few, if any worries regarding the potential for abuse of market power. We would be in a world not all that different from the ideal world of Economides (2004).

To understand the internet as a critical infrastructure we have decided to focus on the South American region[1], a complex environment, as a first step in that direction. It is nothing more than a first step because the critical infrastructure does not seem to have been identified as such in this particular context. It has not received the attention we believe the internet merits and has seen less government involvement to-date than other infrastructures historically.[2] We would like to emphasize that we ignore other dimensions that may also be considered infrastructures such as internet access, a major concern in Latin America, as in other regions around the world.

The choice of Latin America may seem surprising when considered from the perspective of developed countries. In the past five years, significant progress has been made in disseminating information and communication technologies (ICTs) in Latin America and the Caribbean, with a growing impact on the public, social and economic spheres. The Economic Commission for Latin America and the Caribbean (ECLAC, 2005) reports that between 1998 and 2004, the number of fixed telephones almost doubled, rising from 53 million to close to 93 million; the number of cell phones grew 8.5 times, from 20 million to 172 million, and the number of internet users increased twelve-fold, from 6 million to 72 million. However significant gaps remain and are indeed becoming wider at the level of internet access, with only 14% access in Latin America and the Caribbean compared to over 50% in developed countries. Growth in ICTs faces increasing challenges, as these technologies penetrate sectors of the population where purchasing power is lower and lower.[3]

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1 Part of our motivation for focusing on a regional issue arises from the unique work prepared for South America through private, informal contacts with stakeholders in a number of countries (see section 2). To the best of our knowledge, a similar data base for other regions of the world does not exist today.

2 The internet has been identified as a critical infrastructure in other contexts such as the threat of terrorist attacks (Aviram and Tor, 2003).

3 It is estimated that the 20% richest members of the population in the region dispose of US$800 per year for investing in ICTs, while the 50% poorest can only afford to spend US$100 per year. The poorest 25% of the population have only US$1 per week with which to connect to ICTs (ECLAC, 2005)

Thus the region is coming to the realization that without proactive policies, new approaches to the internet, new technologies can exacerbate existing inequalities, which makes it increasingly important to take public actions that will ensure socially desirable results. As we will see, the analysis of the paper raises the perennial challenge policy makers face in economic development. Should they focus on a few key sectors with the expectation that successful deployment in these sectors will have a knock-on benefit for the whole economy or should they focus instead on uniform deployment of the internet, leaving no one behind. At this stage, the focus appears to be far more on universal service, i.e., an even, geography-free deployment of internet access. India, on the contrary, has resolutely taken a very selective approach, with typical penetration even lower than in South America and with a thriving telecom sector localized mostly in Bangalore (Zaheer and Rajan 2003; Kelly 2005a & b).

To address the “critical infrastructure,” our paper is organized in a bottom-up fashion. Section 2 describes a historical account of a particular segment of the internet in a region of the world impacted by the introduction and deployment of internet infrastructure. This is the history and development of the internet traffic exchange infrastructure in South America. Taking into account the lessons from South America, the paper then analyzes the internet backbone as a critical infrastructure. Section 4 addressed limitations to the positive economic impact of the internet on geographic development. As a preliminary conclusion, section 5 underlines that, as an infrastructure, internet development clearly has policy implications.

2. Internet in Latin America, its emergence, development and market structure

In this section we discuss the emergence, development, market structure and governance of a critical part of the internet infrastructure in Latin America. We refer to the history and development of Network Access Points (NAP).

2.1. The emergence of the internet in Latin America

During the late 1980s, the internet started out as a university-led venture in several Latin American countries, in some cases with an ad-hoc, non-committed participation of government agencies. In several countries a leading academic institution or a small group of universities forged an alliance with the NSF or with a U.S. university to establish a link to the existing NSF backbone. In the mid-1990s, after the commercial internet growth boom in the U.S., the first commercial internet access providers appeared in the region. Some telephone companies began to service corporate customers and households, but newly formed firms and established data network providers also created Internet Service Providers (ISPs).(Husssain, 2001)

Early provider relied on international carriers for access to Internet Backbone Providers (IBPs). In most cases these providers signed transit agreements, as their size and inexperience did not make them suitable for peering agreements. International traffic became mostly unidirectional, with users of the early ISPs getting access to data bases and early web services, mostly located in the USA. Regional customers' internet traffic was routed through networks in the USA, regardless of the geographical location of sources and destinations. As domestic traffic increased, ISPs saw no advantage in having their domestic traffic routed through foreign networks when, in fact, the source and destination points of such traffic were located within the country. To the ISPs it was evident that local routing of domestic internet traffic would save them the costs incurred in purchasing channel capacity in carriers' networks.

In the late 1990s, ISPs in Argentina, Chile, Brazil and Colombia chose to negotiate multilateral cooperative agreements among themselves (in each country, all of them or a selected subset of them) to build traffic exchange points. Participating ISPs, also called members, jointly designated a NAP administrative body in charge of the agreement. This body was usually an association of telecommunication-related firms (chambers of commerce), as was the case in Argentina and Colombia. Throughout the region such cooperative agreements became known as NAPs. NAPs allowed ISPs to avoid routing domestic traffic through the large ISPs routers and gateways in the USA. One of the immediate consequences of the creation of NAPs was a reduction in costs for all ISPs. New ISPs saw the benefits of joining the established associations and participating in the exchange. The NAPs saw major growth in the early years of their existence.

2.2. Interconnection agreements

The two most significant interconnection agreements between ISPs are peering contracts and customer contracts (Huston, 1999). Under a peering arrangement, an ISP accepts traffic destined for its customers and does not accept transit traffic destined for a third ISP´s customers. With a customer agreement, an ISP sells transit to another ISP; enabling the latter's customers to communicate with the rest of the internet. A peering agreement usually implies no charges among ISPs, so it is considered a Bill and Keep (B&K) agreement. Under B&K, ISPs do not charge each other for traffic exchanged between their networks. A peering contract involves address advertising, settlements and peer monitoring of interconnection features. (Norton, 2003)

These two types of agreements help to consolidate the hierarchical structure observed in the internet. Less complex routing tables, a limitation on routing arbitrage, the reduction in connection costs and an improvement in the accountability of providers' quality of service are usually listed as the benefits of the hierarchical structure.

However, the internet is not purely hierarchical. The South American internet access markets are examples of regional secondary peering agreements for the exchange of local and regional traffic. Many of the ISPs involved also benefit from the practice of being customers to multiple backbones (multi homing). (Hussain, 2001)

2.3. The nature and extent of regulatory intervention

Two cases of regulatory intervention in the internet access market are worth mentioning: Chile and Venezuela.

The Chilean Department of Transportation and Telecommunications, through its Telecommunications Sub Secretariat, regulates ISPs' interconnection in Chile (Subtel, 2000). The Secretariat´s intervention is aimed at guaranteeing efficient use of resources and the non-discriminatory treatment of users´ access to contents, independently from network access providers. Regulatory norms constrain ISPs to establish and accept connections among themselves to send domestic traffic, leading to the set-up of traffic exchange points, called TEPs (Traffic Exchange Point), for domestic traffic.[4]

[4] TEPs are actually a regulatory concept and a first step towards understanding what traffic exchange is both from a legal and technical point of view. In short, Chilean-based ISPs are obliged to become TEPs because they are mandated to establish local interconnectivity to other

TEPs must be non-discriminatory and must accept all ISPs' domestic traffic, without restrictions, and exchange routes with ISPs connected to other TEPs. In order to comply with the domestic connection requirement, every ISP must be physically connected to and entitled to route exchange with at least one TEP. In this case, the existing agreement among ISPs connected to TEP should be a peering agreement. They may, however, agree on other connection topologies, provided that national traffic be exchanged by authorized providers.

TEPs manage quality indicators not only of TEP connections with ISPs, but also of connections among TEPs. By mandate of the Telecommunications Authority, there must be full connectivity among TEPs, if less than five in number. However, should there be more than five, each TEP has to be connected to another three TEPs.

In another country, Venezuela, the NAP has just been created, promoted by Casetel (Chamber of Telecommunications), Conatel (National Telecommunications Regulatory Commission) and the Venezuelan Chamber of Electronic Commerce. The NAP is a result of Conatel´s institutional mission to promote internet deployment in the country (Convergencia Latina, 2003).

2.4. NAPs in South America

2.4.1. NAP Cabase Argentina

In Argentina NAP Cabase Argentina was founded in April 1998. NAP Cabase was created by the *Cámara Argentina de Bases de Datos y Servicios en Linea* (Argentinian Chamber of Data Base and On-line Services), a lobbying organization, as a non-profit body embracing all 12 Argentinian telecommunications companies, on-line and internet service providers. Cabase contracted Comsat Argentina to operate and maintain the NAP. To qualify as a NAP member, a company must first be a Cabase member, have an added value or telecommunications license, and own an Autonomous System number. In 2003, NAP Cabase's ISPs had about 71,500 dial-up connections - 90% of the country's connections - 120 000 ADSL connections, and over 73 000 cable customers. NAP Cabase handled

ISPs. On the other hand, NAP is the realization of a TEP in which several ISPs associate to establish a legal entity able whose purpose is the exchange of local traffic under independent governance.

almost 100% of internet domestic traffic. Other types of traffic are handled by agreements signed by individual ISPs with international carriers (Bellagamba, 2003).

Prior to NAP construction, ISPs had to pay an expensive international access charge to communicate with other ISPs at a local level. Data access and e-mail providers (whose clients are mainly corporate) operated an X.25 network. After the update to IP, Argentine communications authorities allowed Telintar to be the sole provider of international access, but Telintar did not provide local connectivity. The local connectivity issue was first addressed when three Argentine ISPs decided to interconnect themselves. After one year of negotiations the three ISPs decided that they would be bound by a local interconnection neutral agreement. This agreement became NAP CAbase. Original founding members paid no entry fees.

The terms of the agreement are the same for all members. Initially some ISPs raised concerns threatening to refuse acceptance of some contract clauses such as ISPs being contractually obliged to publish their domestic routes. In fact the exchange of domestic traffic must take place at no reciprocal costs for the parties involved; all agreements are peering agreements. The administration believes that their determination to keep the same contract for all members has been crucial to the growth in exchanges. There are no private agreements between two ISPs at the NAP. Routing addresses are publicly advertised for all members. The NAP Cabase adheres to an open-policy principle. All business affairs are publicly discussed. The NAP's cooperative spirit led the organization to dismiss the issue of Service Level Agreements.

Cabase's approach to decision-making is that decisions are made together, with a technical sub-commission in which every member is represented by a professional technician. On the other hand, financial sustainability rests on the concept of NAP points. The administration introduced this concept to reflect the use that each ISP makes of the common switching resource. The capacity demanded by each ISP determines the amount of NAP points awarded to it. In other words, an ISP's monthly payments depend on the amount of NAP points it has accumulated. One NAP point encompasses not only connection capacity, but also the kind of installation needed by the ISP.

In 2003 four members (Advance Grupo Telefonica, Impsat, Prima-Grupo Clarin and Telecom Argentina) decided to unilaterally reduce their input capacity to the connection (Bellagamba, 2004). When the four members downgraded their connections the NAP administration could not resort to any punishing action against those ISPs. This situation led to chaos in internet traffic interconnection in Argentina. Other members were obliged to advertise routes while the four ISPs reduced their capacity. This effectively produced two networks in Argentina. Due to the reduction in capacity, the subscribers of the remaining ISPs could not "see" addresses belonging to any of the four ISPs. This was, in fact, a strangling of interconnection, which led to the de facto existence of two subnetworks. As a consequence, any connection between these two subnetworks was only possible using international links. Cabase has admitted some responsibility in this affair since it did not foresee the consequences of not having any Service Level Agreements.

The 4 ISPs have sought economic compensation from the remaining ISPs connected to NAP Cabase. Both sides argued the importance of their own traffic in the Argentine context. If one side demanded compensation, the other side believed that it should also be granted compensation. Eventually the four ISPs decided to disconnect their networks from the NAP.

Ultimately, what the ISPs were pursuing was a change in the nature of the interconnection agreement. The four ISPs sought to enter client-server agreements or perhaps paid peering agreements. However, Cabase's principle of peering public agreements based on a cooperative infrastructure was to stand.

NAP administrators reckon that the action taken by the 4 ISPs may have been motivated by growth in VoIP services. In all events, the 4 ISPs argued that they had made the largest part of the initial investment and demanded compensation in return.

A certain interpretation of the Argentine telecommunications act allowed Cabase to seek the intervention of the *Secretaría de Comunicaciones.* However the government agency never responded to Cabase´s letter.

2.4.2. NAP Chile

NAP Chile was created by six independent ISPs to prevent the international outflow of domestic IP traffic. This association was also the genesis of the *Asociación de Proveedores de Internet*, IPA (Internet Provider Association).

NAP Chile is one of eight TEPs that existed in 2004.It guarantees a non-discrimination policy by which ISPs must accept and establish connections among themselves to exchange domestic traffic. Chile is the only Latin American country in which regulations have been designed to solve the problem of internet interconnection. Specifically, the Chilean Department of Transportation and Telecommunications, through its Telecommunications Sub Secretariat, has taken steps to regulate ISP interconnection in Chile. According to 1999 and 2000 regulatory guidelines, the Telecommunications Secretariat must guarantee, among other things, the efficient use of resources, and non-discriminatory access to contents for users, regardless of their network access provider. In turn, every content provider must be free to choose its hosting provider, which leads to free competition.

The guidelines mentioned seek to establish a non-discriminatory internet access service, in terms of quality, constraining ISPs to establish and accept connections among themselves to send domestic traffic. Red tape for ISPs includes the submission of a written request, a copy of which must be sent to the Sub Secretariat. Established connections should guarantee quality access to users, equivalent not only to that provided by their own ISP, but also to that of the ISP at which interconnection was requested. Regulation also allows for the establishment of traffic exchange points for domestic traffic (Subtel, 1999, 2000).

The Secretariat also controls network functioning by demanding that ISPs keep quality indicators such as the number of users, number of content providers, rate of packets lost, delay levels in data delivery (latency), and links' occupation level, published in a common web page. The rate of packets lost is the percentage of packets sent to a specific destination, but lost and therefore unable to receive an answer during a certain period of time. Latency is the time spent by a packet leaving and going to another specific point of the internet network.

2.4.3. NAP Colombia

An agreement signed by 12 ISPs (founders), led by the Colombian Chamber of Informatics and Telecommunications CCIT, created NAP Colombia in 1998 as a cooperative body. CCIT was donated part of the exchange equipment, outsourcing maintenance, control, and traffic measuring maintenance, control, and traffic measuring. Founding ISPs benefited from the common exchange point. Communication and routing services are rendered under equal conditions and opportunities for all entitled NAP members (NAP Colombia, 2004).

In 2003 it was estimated that Colombian ISPs who are also NAP members save about one million dollar a year, as they are not using international bandwidth to route domestic traffic. Total traffic handled by such providers represents 90% of all domestic traffic.

NAP Colombia provides information about traffic volumes, speed, traffic comparative ratios, time of use and congestion levels. It also updates information on internet development and growth in Colombia, identifying the technical capacities offered, as well as traffic and demand. All information and statistics derived from NAP's operations must be furnished to all parties to the agreement, at the same time and under the same conditions and means, without any discrimination or preference. Peering is the only type of agreement at the NAP.

The NAP Administrative Council acts as decision-making body. If technological changes are implemented by the NAP, the technical subcommittee issues recommendations to be approved by the Administrative Council. Founding members set forth an entrance fee to cover infrastructure expenses. NAP operating costs are financed with a monthly payment set forth by NAP members, whose purpose is to cover projected expenses.

The NAP was originally operated with level 3 technology, which meant that all ISPs were connected under peering agreements (implicit on direct connection to NAP). However, due to a traffic increase through the level 3 router, speed problems appeared as the router was working at full capacity. Consequently, NAP members migrated to level-2 technology, and although this was a technological set back, it allowed each ISP to set up its equipment according to its own traffic requirements. This new scheme may generate interconnection agreements other than peering, but transit agreements have not been signed yet.

The original tariff scheme for each ISP was calculated based on monthly operational costs, and equally divided among all ISPs. However, it did not fairly reflect traffic variations from one ISP to the others. Therefore the NAP had to design new schemes. After a transition period in which 70% of monthly costs were equally divided among all ISPs, with the remaining 30% allocated in proportion to the ISPs' shares of total traffic, NAP Colombia recently moved to a cost allocation scheme similar to that used by NAP Cabase.

2.4.4. NAP Peru

NAP Peru is a non-profit civil association, founded on August 2000 as an independent organization by five founding operators. Key characteristics for internet domestic traffic in Peru improved immediately after NAP Peru began operating. This was due to the fact that international bandwidth was no longer shared with national traffic and costs arising from time of connection, final destination, as well as the network and infrastructure used for the interconnection were reduced. One technical and one administrative committee are in charge of technical and administrative issues, respectively, with the American Chamber of Commerce currently administering the body. As usual, operation, maintenance and traffic measuring are outsourced to a specialized firm.

The main problem faced by this NAP is the result of its original legal framework (a non-profit association instead of an independent, profit-oriented organization), because it does not reflect the existing traffic disparity. Under the original rules all the parties had to connect with the same capacity, and if links were saturated they had to increase their capacity on equal basis. However, this restriction to conform to bandwidth capacity harms small traffic operators. Since NAP Peru is currently saturated, sometimes it is preferable, for the sake of speed, to route traffic to international links. As a result, it was proposed to update the interconnection links to 30 Mbps, but this move pushed out members with less traffic because of the higher interconnection costs incurred.

ISPs partners at NAP Peru convene peer-to-peer exchange agreements. As of early 2004, the two largest ISPs have handled 95% of NAP traffic. For its members, NAP Peru hosts routers and infrastructure for domestic traffic exchange, thus avoiding the use of international links. In case of failure, a report is produced in under five minutes, offering 99.999% availability. Measurements are not, however, classified according traffic type (voice, video, data, etc). The criteria measuring the quality of the services rendered by NAP include bandwidth and latency between the exchange central node and the provider's exchange router. Traffic from each ISP to NAP (outgoing traffic for ISPs) and from the NAP to each ISP (ongoing traffic to ISP) are also considered when evaluating quality of service. Total traffic is also calculated from data levels transiting throughout the two (redundant) switches, which belong to the NAP. Each ISP is connected to each one of these switches (one backs up the other in case of failures).

The entry fee that must be paid by every applicant is USD15,000. Total The NAP's monthly operational cost was about USD3,000 per month in 2003. Such cost is equally divided among its members. If any ISP requests membership to the NAP, it must have an AS number and use BGP, own an international outgoing, and maintain the same transfer speed as the remaining members. The minimum capacity required to interconnect to NAP is 2Mbps. As a result, smaller Peruvian ISPs usually route their internet traffic through transit nodes in the United States.

2.4.5. Brazilian NAPs

NAP Brazil

NAP Brazil is located in Sao Paulo. It is administered and operated by Terremark Latin America (Brazil) Ltd, together with FAPESP (*Fundaçáo de Amparo á Pesquisa do Estado de Sáo Paulo).* Terremark also owns and operates NAP de las Americas, Miami, U.S., the world's 5th network access point Tier-1.

NAP Brazil uses FAPESP's facilities, with some of its expenses covered by Terremark. Among the services offered by the NAP are information provision, peering, and data services. Such an offer also includes physical facilities for equipment to its clients. Each client privately signs up peering agreements and other similar commercial agreements with other member ISPs. NAP acts as a facilitator and operates the peering structure and the meeting points used by its clients for the duration of the agreements. It also sells cross connections at different speed for those clients who may interconnect between themselves. It offers system monitoring, services and other kinds of installations used by four categories of clients: network service transporters or providers, service providers (hosting companies), government commercial and industrial enterprises, and government agencies (Crom et. al, 2003).

NAP clients with two simultaneous connections are offered 99.999% availability to connect with other clients having also two connections. Those with one connection may obtain 99.5% availability, although larger percentages may be possible in some cases.

NAP RSIX (Porto Alegre)

NAP RSIX operates in the data processing center of the Universidad Federal de Rio Grande do Sul. It facilitates agreements and network connection at low costs for public and private institutions. This NAP provides a neutral point where different operators may exchange traffic among different backbones, having at least one point of presence in Brazil.

Some of its first members included Brazilian research and academic institutions, as well as commercial ISPs and other academic Autonomous Systems. Multilateral agreements are signed among these members. Members are required to use protocol BGP4 and have at least 2 Mbps of capacity.

NAP ANSP

This network was created on 1988 thanks to a nuclear physics professor, the president of the FAPESP's Consehho Superior. Originally it had connections that allowed universities and research institutions in Sao Paolo to gain access to information in United States universities and research centers. Ten years later the network started to offer traffic exchange services, thus promoting traffic exchange between backbones and content providers. NAP ANSP owns an international connection laid out directly with Global Crossing (GBLX) at 155 Mbps.

DIVEO - NAP

This NAP was created in 2001 and is the only wholly private NAP in Brazil. Its goal is the exchange of internet consumers and companies in Brazil. It was set up to improve network efficiency and performance. Connected to NAP ANSP and to other operators like Embratel and Global One, it aims to diversify network exchange by using the BGP4 protocol.

The cases above presented lead to the following conclusions:

(a) A key dimension of internet provision is the set-up of backbones that carry traffic between ISPs, but backbones themselves are generally not a source of problems as long as they are properly interconnected.

(b) The key concern is the interconnection between backbones and this takes place at the level of NAPs.

(c) NAPs are organizations created by some process and characterized by their respective governance. Interestingly enough, NAPs can and do differ a lot from one another in Latin America in terms of both their organization and governance.

To understand the impact of the differences between distinct models of NAP organization and governance, it is necessary to state the internet as "critical infrastructure", as the next section will demonstrate.

3. An infrastructure with unique economic characteristics

3.1. Infrastructure: concept and definitions

What is meant by an infrastructure in a modern, complex system such as the internet is, at best, ambiguous. This is not new but, in the case of the internet, it reaches a point rarely experienced in the past. There is a world of difference between the internet and the infrastructures that have preceded it, including the telegraph, telephony, and cable infrastructures.

Our concern is with the internet as a critical infrastructure, rather than with the internet per se. Beyond that, the infrastructure has been selected in a very narrow manner This background information is important in order to understand the specifics of various national internet access infrastructures, but it must also be pointed out that infrastructure exist from the origin of the facilities. Few innovations almost instantly become infrastructures like that of Claude and Ignace Chappe, whose optical semaphore was adopted by the French Legislature shortly before Valmy in 1792 and is said to have played a significant role in keeping the French army better informed. Similarly, there is probably no existing infrastructure that has been studied over as long a historical period as the Chota Nagpur Plateau's irrigation system, which has been analysed for 4,000 years (Sengupta 2001). Few infrastructures are now being put to the test as harshly as those parts of health infrastructures, regionally, nationally, and globally that have to deal with growing concern over the avian flu.

This was not the situation with the internet. It only gradually became an infrastructure. This was even truer for places outside North America such as Latin American where the internet was totally dependent upon access to North America, the location of most of its content. In turn, access was dependent upon both the local access infrastructure, as well as intercontinental access to the North American internet.

In short, an infrastructure is a concept that is both intuitive and complex. When thinking about infrastructures, one thinks of something like "large capital intensive natural monopolies such as highways, other transportation facilities, water and sewer lines, and communications systems" (Gamlich 1994, p. 1177). The internet is complex because, when we start thinking about the concept more carefully, while many activities are not infrastructures, the boundary can nevertheless be quite ambiguous. We must first understand the definition of infrastructures to understand what the significance of saying that the internet is an infrastructure. To that end we review a number of ways that infrastructures have been defined in order to be able to support our contention that the internet is a critical infrastructure of modern economies.

The ambiguity we find in the concept led us to turn to the dictionary to look for a definition. The Webster's New Universal Dictionary defines infrastructures as: "The basic underlying framework or features of a system or organization." It also provides a more concrete definition, closer to the intuitive concept of an infrastructure, namely: "The fundamental facilities and systems serving a country, city, or area, as transportation and communication systems, power plants, and school." This definition gives a concrete dimension to what one means by infrastructure and yet it is easy to see that it overly constrains the first definition, leaving no room for "digital" infrastructures. Our objective is not to provide an ultimate solution to the definition problem, but rather to enhance our understanding of a rich and powerful analytical concept that will help us better understand the infrastructure dimension of the internet.

The term 'infrastructure' is often used to describe some of the physical elements that would be used in a system. Thus, the FCC's overall policy priority is not competition, but the deployment of a broadband infrastructure across the U.S. This is illustrated by Aron and Burnstein (2003) when they argue that, "Consideration must be given to the obligations of incumbents to unbundle their broadband infrastructure and provide pieces of it" (p. 3).[5]

[5] Aron and Burnstein (2003) effectively consider two infrastructures and two scenarios, namely, whether the presence of duopoly-type competition between cable broadband internet access through cable modem and telephone operators' DSL access reduces the price of broadband access relative to a monopoly infrastructure, either cable-based or DSL-based. They do not study whether or not unbundling the service provision of broadband access under unbundling regulation at either the DSL level or at both the DSL and cable levels, i.e., service level competition would provide an even more efficient solution, with greater service diversity and, for comparable services, lower access prices (Bourdeau de Fontenay, Chavez, and Savin 2003 and Bourdeau de Fontenay, Liebenau, Savin 2005).

Their interpretation would seem to be supported by the Webster's use of "facilities." Aschauer (1989) and a whole body of literature on public infrastructure reviewed by Gramlich (1994) takes an even narrower approach to the concept of infrastructure, restricting its attention to public sector ownership of infrastructure capital due to a lack of available data with which to explore any other definitions. Were it not for such data constraints, Gramlich (1994, 1177) would have liked to define the infrastructure of a regional entity such as a country as possibly including, "human capital investment and/or research and development capital." Justman (1995, 131) takes a broader perspective, including "less tangible" elements such as processing facilities and distribution networks.

Aviram and Tor (2003a) take a very different view of what an infrastructure could mean, which is closer to the Webster's first and more generic definition. This would seem to be motivated by the post-9/11 context with the emergence of Homeland Security's Critical Infrastructure Protection Program. That program formally integrates in the concept of infrastructure the governance that supports the exchange of critical data between providers in the context the private stakeholders' incentives to manipulate the process to their private benefit. Their usage brings us closer to the definition by Frischmann (2004) that we consider below.

For them, the formal and actual governance of the various stakeholders is an integral part of the infrastructure. Furthermore, this implies that the institutions and governance among the stakeholders, including the specific government agency (agencies) involved, are together an integral part of the internet infrastructure and by extension, the multiplayer information systems and their ability to communicate with one another. For Aviram (2003e), infrastructures have complementary dimensions that tend to make a significant difference between different areas. Thus, an infrastructure tends to develop institutions and private organizations (often informal) that often have the ability to complement the government's role. When considering the Katrina disaster in late August 2005, Aviram's analysis suggests that informal governance failed, among other things, because of the racial divide that is so specific to the USA. The U.S.' racial divide may have contributed to the region's and country's inability to respond to Katrina as efficiently as many other, less developed countries.

3.2. Infrastructure, government and Coase's lighthouse

Infrastructures are typically associated with large, sunk investments and historically there have been debates among economists as to whether these funds could be effectively provided by the private sector without government intervention. Many economists have proposed price-based mechanisms to allocate access to infrastructures, noting that such a system would prevent overinvestment in infrastructures. Firstly, as we saw with Katrina, even if the price system by itself may allocate according to ability to pay, this is barely an efficient solution in a heterogeneous society, nor is it an efficient approach once one takes the social and political dimensions of the problem into consideration.

The debate around the role of government in the provision of infrastructures appears, at first glance, to have been resolved by Coase's 1974 study of the lighthouse. Few structures have epitomized the role of government in providing for some forms of infrastructures and to that extent Coase's analysis is central to our understanding of the interplay between governments and infrastructures. In practice, the merit of Coase's study was to bring to the forefront, using the very powerful image of the lighthouse, the complexity of the problem. A careful reading of Coase shows that he does not provide a solution to the complex problem discussed. His contribution is to outline a range of options among alternative governance, all of which were already widely known and all of which involve substantial government intervention. None of the solutions discussed involve the free market as conventionally understood (van Zandt 1993).

In his study of the provision of lighthouse services in England and Wales, Coase takes to task a large number of economists for rejecting the possibility that lighthouses could be provided by the private sector, independently of government intervention, funding, and management.[6] Yet none of his solutions conflicts with those considered by those economists. Coase correctly asserts that, "A lighthouse service can be provided by private enterprise" (p. 375). Nevertheless, that sentence, if read in isolation, is grossly misleading since the provision of the service he considers, in every case, was carried out under highly regulated conditions, conditions that were designed to protect the interest of the private entrepreneur who built the lighthouse. The principal risk taken by the entrepreneur was that,

[6] Coase's challenge focuses largely on Samuelson and yet the only criticism made by his paper regarding Samuelson's position is that Samuelson was not informed as to the actual working of the English and Wales' lighthouse arrangements. Samuelson's analysis is far closer to the situation that arose on the European continent as analyzed by van Zandt (1993).

due to unforeseen conditions, the seafaring traffic might shift in such a way that the entrepreneur's earnings would end up be lower than expected.

Coase tells us that the entrepreneur who took the task of building a lighthouse was effectively granted a government monopoly, as well as rates s/he could charge to operate such lighthouse and maintain it. There were other benefits in kind. In those days, most ships would follow the coast, i.e., that they would stop in most ports along their path. Harbours and ports would typically have a customs house that would charge those ships for the use of the port. Typically, that same customs house would collect the charges that related to the lighthouse(s) that the ship had passed since the last port it stopped at. This meant that, contrary to the belief of most economists, transaction costs were quite low. The arrangement eliminated most free riding.

The rates charged were regulated very early on by the charter the entrepreneur would receive and posted in customhouses. In other words, Coase shows that the arrangement was highly regulated so as to avoid the kind of opportunism Mill, Sidgwick, Samuelson, and Arrow were concerned about. While the lighthouses were typically privately financed in those early days, the licenses granted to private entrepreneurs by the government were so restrictive as to eliminate most of the risks entrepreneurs were taking, while providing them with the proper incentives to build, operate, and maintain those lighthouses. In addition, it was typically the entrepreneur who gathered the support of shipowners for a new lighthouse to then propose to the government that a lighthouse be built and, presumably, suggest the terms and conditions under which it could be built. In other words, the entrepreneur was able to minimize risks in building his/her business case. The scarcity of capital and the political process the entrepreneur had to go through was also such as to minimize, if not proscribe, challenges from a competing entrepreneur. Where the terms of conditions were seen as inadequate, these were improved as noted by Coase (p. 365 and p. 366) in the case of the Eddystone Lighthouse. As one can see, the private provision of lighthouses in England and Wales had little to do with "free markets" as commonly understood today. Coase's 1974 analysis confirms the need for major government involvement in the provision of lighthouses. In fact, if we compare the risks taken by a modern utility as described Justice Stouter in, say, Verizon vs. FCC (2002), we can see that lighthouse entrepreneurs were probably taking even less risk than today's utilities.

Evidently, Coase considers numerous examples in which lighthouses were built with private capital under highly regulated conditions. However, his study ends at the point when the system was changed and the provision of lighthouses was centralized and coordinated at a national level. Except for a few superficial comments, he does not carefully study the transformation of the British system, nor some of the potential rational for the transformation. Had he done so, he would have had to confront the questions raised by economists such as Mill, Sidgwick, Samuelson, and Arrow, questions that he dismisses very casually. One of the central questions that those other economists review is how lighthouse owners could be paid by the shipowners who use the lighthouses. In the period Coase studies, most ships would coast relatively short distances, going mostly from port to port. There were evidently ships that traveled along international routes, but those ships had to follow relatively standard routes, at least, for safety. It suggests that it was relatively easy, during that period to assess the lighthouse(s) the ships would have benefited from when they arrived in a port where they had to pay their duties for using the harbour. In other words, it suggests that the types of shipping that were the most common could easily be assessed in terms of the use of lighthouses, hence keeping free riding to a minimum. Starting with Mill, it would seem that economists started to look at a broader and more complex problem, one where lighthouses became more common and more powerful, where ships became freer to follow a greater diversity of routes, i.e., when it was becoming harder and harder to be able to avoid free riding, a question Coase overlooked given his historical coverage.[7]

Coase's model also makes very strong assumptions about the information requirements for identifying the need for a lighthouse and identifying entrepreneurs with the resources to undertake the task. One of the shortcomings of Coase's analysis is its static nature. Technology was a factor that led to the expansion of seafaring, but lighthouses also contributed to the process, hence to the growth in the extent of the market. He overlooks the dynamic elements of investments such as lighthouses that contributed to an expansion of the division of labor, hence to growth, elements that were at the heart of classical analysis. In this sense, he grossly underestimates the benefits of building new lighthouses, and more generally new infrastructures, that helped augment trade.

West (1977) and Keohn (1997) are among the authors who have looked at the characteristics of English institutions at the end of the XVIIIth and

[7] One seems to see a repeat of the problem with social cost where there are too many ambiguities on the part of all parties to be able to support Coase's criticism of other economists (Klink 1994).

beginning of the XIXth century. This was a period for questioning existing institutions and creating new ones. Transportation constraints meant that the country had remained an aggregation of small largely independent regions until then with very limited scope for interregional commercial exchange. In that period, new projects in the form of turnpikes and canals opened the country and rapidly expended what Adam Smith called "the extent of the market" that led to rapid growth through "the division of labour". In that period, governmental institutions were slowly being developed and private capital was often a much faster way of financing canals and similar public works. While this historical period teaches us a lot about the emergence of modern capitalism, it has very little to tell us about complex, modern societies and, for instance, how best to ensure appropriate infrastructures.

Lighthouses and the Elizabethan period are very far from the age of the internet and yet the step we have taken is necessary to dispel the view that unregulated markets are the answer to all problems.[8] Coase's contribution dispels extreme views about governments, in particular the view that government involvement is, by necessity, inefficient and wasteful. Inefficiencies are found both at the levels of governments as within the private sector and it is the kind of governance that regulates government and private activities that matter (Fontenay and Liebenau, 2004). Economics is not an exact science. Rather, as Marshall had stressed it, it is more akin to a biological process where optimization is of use, at best, locally.

Some question what Adam Smith meant by the third duty of governments, the productive duty to build infrastructure that contributes to the facilitation and expansion of trade, most of the time by facilitating transport and expanding the extent of the market (West 1977). At the time of Coase's study of lighthouses, the number of goods and services that were produced and their diversities were still very limited. The dynamic growth that would emerge from the expansion of the division of labour was in its infancy. Intermediate markets were generally poorly developed and where

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8 This view would seem to result from an overly narrow conceptualization of economics as when Knight in *The Economic Organization* (1933), as cited by Swedberg (2003), writes that, "Economics deals with the *social organization* of economic activity" and adds, "[I]n practice its scope is much narrower still; there are many ways in which economic activity may be socially organized, but the predominant method in modern nations is the price system, or free enterprise" pp. 5-6. From such a perspective, transaction costs required for the price system to function are treated like manna from heaven. Infrastructures and their management or regulation by governments are a significant element of those transaction costs that are ignored as being outside the sphere of economics.

they were developed, different activities were typically located close to each other.[9]

One of the key dimensions of modern infrastructures is that they support a very wide range of activities across the economy to an extent that could not have been imagined in the late XVIIIth century. In a modern economy it is not possible to identify all the activities involved, nor the significance of the impact through which those activities are affected, even less the new activities that are created through division of labour-type innovations (Young 1928). In his path-breaking study of the lighthouse, Coase considers infrastructures at a point in history when they were barely beginning to emerge and demonstrates the substantial role government was already playing together with the private sector in facilitating the creation of infrastructures.[10]

3.3. Infrastructures' economic specificity

Infrastructures are economic sectors that produce somewhat unique intermediate goods. Those intermediate goods are unique because they are not inputs into one or a small number of processes, but rather because they are inputs into a whole gamut of upstream processes. Because infrastructures are inputs in so many economic activities, any disruption in their activities has a profound impact on the general level of economic activities.[11] Such disruption, if permitted, can have wide and costly repercussions throughout the economy, significantly lowering social welfare.

Economists have focused heavily on three other dimensions of modern infrastructures, namely, their low levels of excludability and of rivalry and

[9] One can think of Birmingham's small arm industry Stigler (1951) describes so well.

[10] Keohn (1997) notes that "[I]n the second half of the eighteenth century, Parliament approved hundredth of miles of turnpike construction, much of it initiated and funded regionally by local businessmen… At the same time, Wedgewood and Bentley began recruiting political and financial support for a canal that would link the port cities of Liverpool and Hull…" (p. 34).
Note the inconsistency with West's (1977) analysis that argues that the third duty of the state was to build infrastructures such as roads and canals because it was very hard to find private financing. That might have been more common in France where Turgot was urging the government to take an active role in building infrastructures (Hart, undated).

[11] This is why, in modern warfare, so many resources are targeted at destroying the enemy's infrastructures. This is also why, after a war, infrastructure rebuilding becomes the dominant activity, an activity that can never start without significant and durable, direct government intervention. This dimension of infrastructures and of the role governments have to play has rarely been as well demonstrated as by the Marshall Plan after World War II.

their high level of externalities (de Fontenay, Hogendorn, and Liebenau 2005). As we noted, those dimensions were fairly minor in the period studied by Coase (West 1977) to become, as noted by Young (1928), central in modern days. The change in the relative role of infrastructures, just like the change in the relative scale of government to make capitalistic trade possible, are dimensions that have been largely neglected by economists. This kind of change is somewhat reflected in modern telecommunications. In the 1980s/early 1990s, industries such as the automobile sector built costly, complex, dedicated, private networks based on proprietary networks – a pre-internet infrastructure very much like the canal which would help Wedgeworth's Etruria factory on the Trent-Mersey canal to facilitate the distribution of its output (Keohn, 1997) or the early railroads with their individual gauges. Today's industry networks are centered on a single, universal infrastructure, namely the internet.

Rose (1986) has focused on the third, specific dimension of infrastructures, a dimension that we have repeatedly described above, but not yet specified, namely externalities. Rose makes the simple, Youngian observation that looking at an infrastructure from a neoclassical perspective, i.e., as an essentially static process, and basing policies such as pricing upon that perspective is harmful to the economy because it undermines the very benefit infrastructures contribute to, namely, the expansion of trade.[12] Rose's contribution shows that extending Coase's analysis to the stage when the activity becomes an infrastructure is not a neutral step. It is at the heart of the economy's innovative process and the source of economic development.

We have identified up to this stage a number of characteristics that make infrastructures different from conventional economic goods, characteristics such as their impact over a broad range of downstream economic activities, low levels of excludability and rivalry and a high level of externalities.

[12] This issue, the role of externality, separated Young more than any other issues from his student, Knight. The externalities are the core of Young's analysis to a much greater extent than to Marshall. Young and Marshall, notwithstanding West's analysis, see those as core to Smith's growth analysis all centered on the division of labor (theory Young brilliantly generalized).
Knight was one of the first and one of the most outspoken neoclassicists to reject externalities. Today's conventional economics is in the tradition of Knight rather than Young, because Knight's static approach was amenable to clear solutions that could be established unambiguously given the assumptions the economic analysis was based on.

4. The internet's economic benefits are limited by its impact on geographic development

Each new technological revolution in transportation and/or communications transforms the world we live in and shrinks distances. One will soon be able to work from anywhere and "geography" will become irrelevant, or so we foresee the impact of each new technologicaladvance. Keohn (1997) reports that when the first locomotive, the 'Rocket' was introduced, it could reach the speed of 25 mph. It could cover in one hour what a loaded horse-drawn wagon could do, at best, in one full day on the new turnpikes. The introduction of the telegraph had an even greater effect on society (Standage 1998). Events that had been taking days and often months to reach people in major metropolitan centers such as London became available almost instantly. Later, television and satellites brought about the same changes for video images.[13]

The demise of geography via the internet is yet to be realized. With each transformation throughout history, conditions have changed with some regions benefiting while others lose out, but the process has been slow and the "geography" evolves, changes, but does not disappear. There are many factors that can help us to understand the ever-present geography, the most obvious being the lack of mobility of populations.

Marshall (1890) is probably the first to have studied the role of economic geography in the context of the localization of business activities. As a pragmatic man, he could not ignore that economies of scale were a major factor in the economy and that monopolies were nevertheless uncommon. Marshall addressed the conflict by noting that there are substantial externalities between firms within a given industry. They worked in such a way as to dissipate those externalities throughout the sector, resulting in the absence of monopolies. He was aware of the potential dichotomy between economies of scale-based monopolies and their incompatibility with competition, which became the neoclassical dilemma, but he dismissed it for the interaction between externalities and geography, i.e., where firms are located.

[13] In 1954, the Canadian Broadcasting Corporation was the first to present the film of Queen Elizabeth II's coronation on North American television. It did so by using a jet bomber belonging to the Royal Canadian Air Force to bring the films from Europe to North America. The first live broadcast between Europe and North America did not take place until 1959.

Neoclassicists have rejected Marshall's externalities. After all, as Sraffa (1926) points out, it makes a mess in the formal analysis of the problem. They have effectively marginalized externalities. Assuming away externalities, one is left with the neoclassical dichotomy between monopolies and 'perfect competition,' with nothing in between. At the same time, one also eliminates geography from economic analysis.

The policy issue with economic geography is that, independent of internet's communication capabilities, geography still matters a great deal. Kogut (2003) edited a number of studies on internet development in a number of countries, including India. The series of papers that he edited is very enlightening and provides an insight into the role of geography. Leamer and Sorper (2001) first attacked the subject from its traditional perspective. Trading is a function of the distance between traders and the further from each other traders are, the less they generally trade with each other. They then turn to complementary factors to evaluate whether there are internet-specific factors that may be changing that historical relationship. They note the fundamental role played by codification, i.e., the extent to which human communications can be codified.

Some communications can be, through experience, highly codified. The easier it is to codify communications the less sophisiticated are the communication needs to achieve an efficient transfer of information. For instance, one of Apple's historical competitive advantages has been its consistent, superior ability to codify the procedure to start using computers and other appliances they sold to the general public. The most codified forms of communications leave few ambiguities and involve few, if any, elements that could lead to different interpretation. The internet tends to reduce not the geography factor, but at least the significance of distance. Leaner and Sorper (2001) point out that the internet's contribution has to be compared to older technologies such as the telegraph, then the telephone and the fax. Those technologies had already started to impact the role of distance in trade, communications, and distributed work.

Leaner and Sorper (2001) note that, on the other hand, there are communications that are hard to codify; in these situations, one tends to use case studies to facilitate communication that keeps nevertheless many of its ambiguities. Beyond that, there are human communications that cannot be reduced to codifications as, for instance, most great poetry.[14]

The key dimension of their contribution is that, in spite of the gainms we have made in the codification of information that is communicated between humans, there always remain a very substantial amount of communications that, at this stage, cannot be codified. One can think of some of the forms of learning, the exchange of personal views on a subject matter, and other forms of communication; especially those that involve the complex transfer of information, much of which is ad hoc and cannot be pre-planned, but still requires direct, live, human interaction. The lesson to be learnt from their work is that the unique characteristics of these communications imply a continued and substantial role for geography. This can be illustrated by internet's inability to eliminate the existence, even in the high tech sector, of phenomena such as Silicon Valley and Route 128 where localization is just as important as the one Marshall was discussing in his time (Kenney and von Burg 1999; Saxenian 1999). The implications of such a geography is that one must expect the poles of internet-based development, especially at the higher levels, where codification is non-existent and at this stage impossible, are almost exclusively located on the West and East coast, with a minimum role played by the central regions of the country. We raised earlier the example of India and Bangalore (see also Saxenian 2000). It is important for countries, such as in South America, to understand the logic behind that kind of development process whereby the internet tends to reallocate tasks and how it can be expected to impact development: Are one or more "Bangalore-type Silicon Valley" important for the future of South America?

While the process is often affected by e-government – after all, governments are generally the largest centers of activities in most countries, it is largely independent of universal service concerns. Universal service is a policy that aims to eliminate geography while the internet's impact on geography is to transform its role and, in many cases, accentuate its significance.

5. Preliminary conclusions

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[14] This is well known in a great number of contexts. One can think, for instance, at the typical impossibility to write complete contracts, problem that has led to a substantial literature on opportunism (Williamson, 1973) and its challenge (Helper et al., 2000).

The character of the internet as an infrastructure leads to policy implications for governments. Critical infrastructures are segments of the economy that a large number of other segments depend on to function. One thinks typically of transportation, for instance. Their impact on the rest of the economy, along with the cost and damages that arise from infrastructure failures, have always made them a matter of concern for governments.

As an infrastructure, the internet is a unique kind of good that is an input to a very large range of economic activities. Internet disruptions cannot be studied from the same perspective as disruption of average economic processes because their repercussions across the economy would be too serious, costly and politically unacceptable.

Considering the internet as an infrastructure can help Latin American regulators to design their second-generation reform of Universal Access Funds (UAF). Strong mobile penetration in the region helps to achieve universalization goals much more then fixed line penetration, which has stagnated after the post-privatisation boom. The UAF were originally intended to build and support fixed line penetration, but the internet is a serious candidate for receiving assistance from the UAF. Thinking of the internet as an infrastructure can give regulators new criteria in their task of allocating some parts of the UAF to foster internet penetration.

We do not propose a specific infrastructure policy, but we show that governments need to put in place policies that enable them to address potential disruptions. We do not propose specific policies because at this stage too little is known about internet backbone competition and how networks interact with one another. However, we point to the situation in Latin America that has been studied in great detail by one of the authors and shows the enormous diversity in organization and governance at the level of the points of internet traffic exchange or NAPs[15].

Understanding the significance of the internet as an infrastructure and highlighting the diversity of NAP organizations, governance, and organizational routines (Nelson and Winter, 1982) should greatly help governments to assess and compare the efficiency of the present arrangements, their robustness in terms of anticompetitive activities and their ability to cope with significant market disruptions. This should, in turn,

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15 Network Access Points.

help governments to shape policies to address the infrastructure dimension of internet and protect it against critical changes.

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