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Redesigning territories: the case of France's broadband network in the light of regional development and public policies.

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Abstract

In applying a cartographical approach from geographic science for how space can be redefined and measured, this study establishes the anamorphic map of France showing the effect of distance reduction caused by the use of modern telecommunication networks. As the modification of transportation systems, whatever the scale, redesigns territory and creates barriers to regional development, the reduction of "digital divide" has become the goal for French local authorities and government's policy of equity aiming at making territory more attractive and less heterogeneous. In order to represent the shape of France determined by the capacity of existing broadband internet network, we investigate the contraction of space caused by the relay channels of interurban internet network and its accessibility. We define the informational distance as based on a single measure of time span during which information is delivered from a source node to a destination node trough existing relay network. Controlling for a large set of technical constraints, we build the informational map of France using multidimensional scaling and interpolation. We find the informational distance quite uniform between big and medium-size cities. On the contrary, we observe an important dilatation of the urban and rural space at the local loop scale (particularly the "département" level, that is an intermediate French level of local territorial organization, between town and country). While the hyperconnectivity has become the driving force in modern telecommunications, requiring carriers to provide blistering speeds and full-service networks, we also measure the quality of network and the variety of services proposed by service providers. This measure, in turn, shows a more consequential fragmentation of the national territory. Huge private and public investments, especially those induced by local authorities, in the field of broadband infrastructure, create very complex informational anisotropies and probably as a consequence, economic anisotropies in France, between "départements" and within "départements". The "digital divide" seems to be multi-scale: if the "informational distance" is reduced by the "info-communications industry" [1] , it is not an isotropic reduction neither at the nation nor at the "département" scale in France. Broadband networks have created perturbations in the geographic and economic spaces : "digital divide" is a multi-scale divide.

Key words: *Industrial Organization, Infrastructure Economic Policy and Planning, Telecommunications, Cartographic Transformations*,

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[1] See Steffensen (1998) for a definition of "info-communications industry".

JEL classification: *E6*, *F*,*I3*, *L*, *O*, *P*,*R*,

I Motivation

Electronic communications have been more and more omnipresent in all exchanges over the world since the 90's. From an economic and geographical perspective, this informational development undoubtedly *do* transform territories. Thus, it becomes essential to debate whether this fast "informational development" creates any "informational anisotropies" (i.e. "informational anisotropic areas or territories"), occurring even in developed countries like France. In others words, one would know what factors make information (codified knowledge, data), or tacit knowledge, spread uniformly through territories? Is it because of the different characteristics, features and topologies of telecommunication infrastructures and networks? Furthermore, if these "informational anisotropic areas" do exist, do they induce an "informational geography" that is different from "physical geography"?

The objective of our research is threefold. First, we propose a method and generic tools to answer questions stated above. Second, taking the example of France, we want to test the relevance of these tools on a territory for which we have sufficient information to assess the illustrative, explanatory or predictive nature of method proposed and the relevance of the causal relationships proposed. Third, we wish to consider applying of such a study method, in broader perspective, to investigate the impact of infrastructure investment on economic geography. Indeed, the multi-modality should certainly be considered between the technical networks of different nature, such as transport networks and telecommunications networks that are both complementary and interchangeable.

To achieve these objectives, we propose an analytical methodology that consists in using the case of France to identify anisotropies, characterize and then visualize them through appropriate cartographic representations, i.e. cartograms (or anamorphic maps) that can be "thematic" (scalar), or "differential" (vector). In the case of France's center - periphery, inter-cities or inter -"départements"[2] relations, vector anamorphosis (uni-or multi-polar) can be proposed. In the same way as we can portray the quality of high speed rail (e.g. TGV in France) affecting national territory using an anamorphic map, we may apply the same tool for visualizing the quality of the inter-areas telecommunication networks (upstream of the local loop) in the field of electronic communications. In the case of intra-territory approach, i.e. within territories, a scalar anamorphosis such "departments - surface areas" with different variables can be proposed. This is our tool

[2]In France, Département is one of the intermediate levels of local authority between city and nation.

for visualizing the quality of the local loop network for electronic communications.

More generally, if different factors influence the "informational geography" in terms of "industrial organization", a series of questions appears about informational anisotropies noted. Are they influenced solely by the "basic conditions" of the broadband industry (or electronic communications industry or "info-communications industry"), in particular their legal, technical and economic environment? Specifically, what role does the regulation of electronic communications industry play, in the process of unbundling of the local loop (in France, the Law of telecommunications deregulation and privatization of France Telecom (1996) and transposition into French Law of European directives on electronic communications (2002))? At the national level, legislative and regulatory conditions, and, at local level, the intervention of local authorities in construction of telecommunications infrastructure and supply of telecommunications services to the public [3] can also help to explain these informational anisotropies? Do other public policies on economic development and planning play an explanatory role in this process?

In the case of France, if the characteristics of the electronic communications market or "info-communications industry" (basic conditions, strategies, structures, performances) are sufficient to explain the anisotropies observed, then an informational anamorphic map ("départments" - surface areas) based on quality and accessibility features of broadband networks would have the same allure as a scalar anamorphic map ("départments" - surface areas) based on regional income and its growth. Indeed, industrial economics explains that operators of electronic communications industry invest where the market potential is most promising i.e. where GDP is the highest and where it has the highest rate of growth. On the other hand, if the anamorphic maps have not got the same allure, we must look for other factors, including local public policies.

The paper is organized in the following way: section one presents a review of both infrastructure and cartographical methods literature; section two describes our empirical strategy, while the next section focuses on data and cartogram-building procedure; section 4 in turn, presents the results which are discussed and commented; section 5 debates policy-oriented questions and the last section concludes.

II Literature Review

The literature review covers first the general rationale for the investment in infrastructure, and second, the literature relating to the use of cartographical techniques in the domains of urban development and spatial

[3] "Public Network Initiatives" under the provisions of sections of "Code Général des Collectivités Territoriales" L1511-6 (1995) and L1425-1 (2004).

planning.

I Infrastructure and growth

In this section we provide a quick overview of recent literature on the effects of infrastructure on economic growth. For the sake of brevity, the discussion is selective rather than exhaustive.

Among economists, there is a consensus concerning the need to improve infrastructure, which is seen as a necessary condition for successful economic growth[4]. The emphasis on the provision of infrastructure hardware (transportation, telecommunication, information processing) has become a major component of modern growth theories, new economic geography literature and one of the most important topics of the economic policy's debate worldwide. The methodologies used in the infrastructure impact on growth's analysis depend on time horizon (short-term / long term), space dimension (local, regional, national, cross-country), financing structure (public, private, mixed) and frequently on particular assessment needs of study commissioners.

In the macroeconomic literature, a number of studies have found empirical support for a positive impact of infrastructure on aggregate output. For instance, Aschauer (2000) finds that the stock of public infrastructure capital is a significant determinant of aggregate total factor of productivity (despite the fact that economic significance of his results was judged too large by followers). More recent works empirically prove the influence of infrastructure on output growth. For instance, cross-country panel data are used by Canning (1999) and Demetriades and Mamuneas (2000) to confirm infrastructure-growth relation. Röller and Waverman (2001) report large output effects of telecommunications infrastructure in industrial countries, in a framework that controls for the possible endogeneity of infrastructure accumulation. This finding has been verified by the robust results of Calderón and Servén (2004) cross-country long-term study proving that growth is positively affected by the stock of infrastructure assets and that the income inequality declines with higher infrastructure quantity and quality. Some recent papers enhance the role of infrastructure investment as a key instrument of regional development (for example Nijkamp (1986)) while others focus on redistributive and welfare effects of creating facilities (Baldwin and Dixon (2008)).

[4] See for example, Harris (2003), Sader (2000), World Bank (2006), Estache (2006) for broadly similar perspectives.

II Literature review on cartographical methods applied to infrastructure research

Because transportation systems exist at least within two dimensions (*geographic* dimension and *time-space* dimension induced by the travel time within a given geographic space), different methods to explore and visualize these cross-dimensional relations have already emerged back in the 1960s. However, those pioneering tools have not been sufficiently productive in handling and processing large geographic data until the spread of geographic information systems and the development of multidimensional scaling and bidimensional regression transformation techniques in early 1970s.

Mapping of time-spaces based on the heterogenous concept of distance is abundant in literature[5]. In the seminal work of Bunge (1960), two time-maps of Seattle are presented: the first one employs isochrones (lines of equal travel time) to depict travel times from a given origin while the second map is distorted by the isochrones forming concentric circles from a given origin. A body of policy-oriented work was based on the use of time-space transformation methods. For instance, Marchand (1973) applies multidimensional scaling to investigate development of regional inter-urban transportation network in Venezuela; mapping of travel times within the network results in diminution of time-space dimensionality wherever the road network becomes more homogenous. Weir (1975) analyzes the impact of different traces of by-passing freeway around the State College, Pennsylvania, USA, giving an example of the use of time-space map in transportation planning. A time-space anamorphic cartography is applied by Shimizu (1992) expressing contraction of Japan territory due to the development of the high-speed train networks since 1962. A similar method is applied by Spierkermann *et al.* (1993) to represent a space-time anamorphic map of France transformed by the TGV train line linking Paris to Lyon; a multidimensional scaling and interpolation with triangulation is undertaken to visualize the global contraction of French space as well as some specific distortions alongside the TGV line. Associated policy consideration pledging in favour of high-speed networks development has often been, however, subject to some critics (L'Hostis (2000,2003), Murayama (1994), Mathis (2007)) pointing out, among others, the loss in the network's accessibility as a collateral damage to the reduction of space-time dimension. Recently, the chronomaps techniques (space-time relief maps) has been used to represent the complex phenomenon of contraction and dilatation of space time caused by the coexistence of modes of transport with different performances. L'Hostis (2009) applies a chronomap tool to represent three-dimensional visualization of the USA territory distorted by the multimodal network (terrestrial and air).

[5]For an exhaustive review of time-space transformation techniques see Ahmed and Miller (2007).

III Empirical strategy

Since our major interest is to assess the efficiency of public policies affecting electronic telecommunication sector's development in France, we shall recall that investing in this kind of hardware infrastructure has recently gained a fuller recognition as being a "driving force" of the "knowledge-based economy"[6]. That technological change boosts growth is hardly news for economists and policy makers, however, transforming knowledge and information into performing system of its diffusion and use is not an easy task, especially nowadays, in the "digital revolution" era of the information technology development. Nevertheless, that development of innovative technologies speeds economics growth trough, among others, labor force channel, is rather unquestionable; thus, achieving of the "information society", where a majority of workers is producing, handling and distributing information or codified knowledge, has become one of the most important policy concerns.

From this point of view, carrying of a sound and fair town and country planning policy related to spreading of high-speed electronic telecommunication networks has been extremely dynamic in France[7]. In order to portray the country's position towards efficient and accessible broadband network coverage, we apply a two-step procedure. First, we construct an anamorphic map of France based on the "informational distance" within the existing broadband network established by commercial providers. Second, we investigate whether resulting outlying territories (those where the development of modern network has been insufficient) match with the map showing the "Public Initiative Network" (French locally-inspired public initiatives aiming at reducing the gap of broadband network development).

I Methodology

In order to better render the shape of France's territory affected by the broadband network development, we use the mapping anamorphosis techniques.

Historically, *cartograms* (anamorphic maps) have been used by geographers as a complementary tool in visualizing some phenomena frequently misrepresented in the traditional cartography (big cities, for instance), or, more generally, to deal with the density of miscellaneous phenomena that obviously varies across the space (like population, botanical species, etc.). These methods consists of reshaping the real map in the way its *polygons*' surface is resized according to some external geography-related parameter. A key motivation for constructing cartograms is to adjust geographical dimension for the ease of information visualization purposes. Several categories of map deformation's techniques exist.[8], They can be be classified by their ability to maintain the following properties: continuous topology, perimeter preservation, and conformal mapping.

[6] See OECD (1996) for a detailed clarification.

[7] See ARCEP (2008).

[8] See Keim (2005 *et al.*) or Guseyn-Zade, S.M. and V.S. Tikunov (1994) for a detailed review.

Among them, *scalar* and *vector* anamorphosis are the most broadly used.

Scalar anamorphosis permits representing of scalar data (one-dimensional quantitative variable) phenomena; in this type of cartogram, the geographical area is proportionally scaled to the associated descriptive variable's values. The area becomes thus dilated or contracted depending on whether the descriptive variable's value lies, respectively, above or below of its average value). In the Figure 1, the size of each territory shows the relative proportion of the world's population living there[9]. India, China and Japan appear large on the map because they have large populations. Panama, Namibia and Guinea-Bissau have small populations so are barely visible on the map.

-Insert Figure 1 here-

Vector anamorphosis employs vector transformation calculus to find relative position of locations regardless the existence of a given connection pattern (like displacement distance, similarities) between them. This method has been applied, among others, to investigate the accessibility issues of transportation networks. In this case, the speed variation alongside the network grid can be visualized using vectors that link a given city (principal pole) to the others (secondary poles). The use of vectors draws nearer two locations if the accessibility speed of the secondary pole exceeds the average accessibility speed within the network, or keeps them more distant in the opposite situation. The *unipolar* cartogram results from a single origin vectors, while the *multipolar* one aggregates all unipolar vector sets. In the Figure 2, an example of a multipolar vector cartogram is presented: France's national territory is transformed according to travel time. Vector anamorphosis has deformed regular surface grid revealing a large contraction of south-eastern and north-eastern part of France due to the access to the high-speed train network.

-Insert Figure 2 here-

IV Data and intermediary results

Having presented current cartogram-building techniques leads us to justify our methodological approach in this study. Measuring of the "informational distance" follows much the same logic as measuring of the accessibility of transportation systems. More precisely, the analogy between train network and telecommunication network is straightforward: a tourist, traveling form point A to point B by train, has no choice but to follow the existing rail network exactly in the same way the digital information cannot be transmitted otherwise

[9] ©SASI Group (University of Sheffield).

than trough wire network. Hence, it becomes clear that networks do transform territories: establishing connections between locations facilitates and improves exchanges, which, in turn, shortens the distance between them.

Because information travels at the speed of light trough the network, any variation in its travel time might be undistinguishable. Thus, creating a map that would visualize "informational distance" may be an astonishing and purely theoretical idea. However, one should remember that the use of information technology unceasingly grows, pushing existing networks to their limits (with the spread visiophony or telecommuting, for example). In this situation, the congestion issue of widely used networks that makes them performing poorly at some sections, becomes a rationale for measuring of "informational distance".

I The impact of optical fiber infrastructure

The first step in our cartographic processus consists of establishing a real map of France's broadband network. In order to do so, we superimpose the optic fiber grids of five internet provider companies to get an uniform map of broadband network having the same technical characteristics. The outcome is depicted in the Figure 3: a quick look at this map brings to light the heterogeneity of network coverage.

-Insert Figure 3 here-

The next step is to realize France's multipolar vector cartogram portraying the impact of fiber wires on national territory. This step requires the pre-processing of geodata to be used for scaling. We use *KYST* software to calculate the all-pairs shortest-paths (*orthodromic distances*) matrix among a set of origins and destinations (38 French cities).[10] To proceed with scaling *KYST* software uses the shortest paths matrix as input and generates another matrix containing the coordinates of points in space. Then, we use *AnaVect* software[11] to build a deformation matrix (taking into account fiber broadband network infrastructure). The anamorphed map is presented in the Figure 4.

-Insert Figure 4 here-

The existing infrastructure evidently brings closer some locations forming the following groups:

1. : Brest, Rennes, Le Mans, Caen
2. : Orléans, Lyon
3. : Nice, Gap
4. : Bordeaux, Bayonne, Poitiers, Limoges, La Rochelle.

[10] See Kruskal (1964a and 1964b) and Young (1973) for a technical explanation.

[11] See `http://www.univ-rouen.fr/MTG/PatriceLanglois2.htm` for more details.

Furthermore, the most peripheral regions (Brittany, Pas-de-Calais, Basque country, French Riviera) have become recentered in a ball-like shape.

II Data travel time cartogram

The basic cartogram of France presented above has been constructed on the sole network unfolding basis. In order to shift its explanatory power, it needs to be completed. As a matter of fact, recall that measuring of the "informational distance" implies a further investigation on any factors that may possibly affect space dimension of the distance. Among them, time is indisputably, the most revealing one. Therefore, our next step is to find possibly the best method of measuring data travel time.

In order to get the uniform information on data travel time, we have applied the popular *pinging* procedure. This computer network administration utility comes out with two measures. The first one, called *time to live* or simply *ttl*, can be thought as an upper bound on the time that a data packet can exist in an internet system (the grater ttl value is, the less probably a data packet reaches its destination), while the second measure, *response time*, quantifies round-trip time during which information is delivered from a source node to a destination node trough the existing relay network. Although theoretically simple, the practical implementation of *pinging* procedure does not seem, however, to be straightforward in our particular context. France's broadband network linking 38 cities would suggest computing 703 travel times values (from every single location to 37 destinations) and finally reduced to 96 real links in the broadband network. We could not, however, pursue this procedure due to the difficulties associated with gathering and handling specific data. More precisely, the first problem that we have encountered while preparing pinging procedure was to find local servers that IP address would exactly fit the geographical area (which is, by the way, rarely the case). Our second concern was to deal with practical limitation of taking measures in every single location. Therefore, we have decided to make Paris the principal pole (network node) and, subsequently, to process with data travel time calculation from capital city to 37 peripheral locations. Obtaining these values permits us to undertake an unipolar vector anamorphosis within $KYST$ and $AnaVect$ software environments (the scaling procedure generates displacements vectors which, in turn, show the pattern of deviations of time-space from the geographic space). Despite all procedural limitations described above, Fig. 5 a and 6 captures the essence of the "informational distance" in France.

-Insert Figure 5 and 6 here-

At first sight, our results might seem somewhat unexpected: on the cartogram, a city located close to Paris, like Amiens, gets as distant as Nice or Montpellier. Thus, the real distance becomes insignificant. It suggests that fiber wires linking Paris to provincial cities are rather smoothly and uniformly unfolded.

However, some limits might exist at the local network loop level. Moreover, our pinging procedure is based on small data packet (64 kB), making that "informational distance" reflects more the number of intermediary routers (fixed turnaround time) than the real inter-city travel time (varying time). Adding the isochronic circles (Fig. 7) to the previous cartograms renders even better the uniform "informational distance".

-Insert Figure 7 here-

III Network quality cartogram

In this section, we focus on the quality and accessibility dimensions of France's broadband network. We believe that these intrinsic features of physical infrastructure cannot be put aside. They are extremely important from both user's and policy-makers' point of view. Therefore, we have decided to concentrate on a department level. A disaggregated level of analysis, enables us to raise the regional cohesion policy question referring to modern telecommunication networks.

Network quality measures. Assessing the quality of network is based on the following criteria: network bandwidth and available services. In order to capture the quality dimension of network, we compute for each department's surface a composite quality index which embraces, first, broadband-wire coverage rate (ADSL, ADSL2+, ADSL TV or Fiber), second, effective uploading bandwidth (taking into account the real bandwidth loss within a zone), and finally, average number of services available within a line (ADSL, Triple Play, HDTV). Each index factor is equally weighted and additive, yielding the overall quality score. Scalar morphing of France departmental map proportionally to the broadband quality index is depicted in the Fig. 8.

-Insert Figure 8 here-

The most dilated area corresponds to Ile-de-France region. Not surprisingly, Paris and surrounding departments rank first in terms of network quality, with its surface filled with abundant and efficient broadband infrastructure, followed by Belfort Territory, a small department of 200 km2. This rather unexpected newcomer indeed outperforms bigger and economically richer regions like PACA thanks to its high ADSL TV and Fiber coverage. Then come Rhône and Haute-Garonne, which is not astonishing either, because these departments harbor Lyon and Toulouse, respectively the 2nd and the 4th biggest French agglomerations. Eastern border departments (like Moselle and...) are also well-classified contrary to centrally situated ones, that visibly suffer from underdevelopment of broadband infrastructure.

Network accessibility measures Network accessibility is essentially based on the following criteria: the existence of an offer itself, its pricing, and connection waiting time.

Some considerations have to be made concerning the choice of the evaluation factors mentioned above. The first important remark concerns pricing. The final consumer price of an offer predominantly depends on an associated bandwidth, though implicitly, on the variety of services. However, recall from the previous section, that these were network quality evaluation features. Therefore, we prefer not to use the pricing criterion at this time, in order to avoid spurious results (in the way that more weight would be given to network quality measures). The price dimension can be easily approximated by the local-loop unbundling rate instead. This is because an unbundled line decreases the accessibility price. The second remark raises the problem of gathering reliable information on connection waiting time. Unfortunately, these data were not available at the time of our study, compelling us to find an alternative solution. It turned out that measuring a number of internet providers within a line would be a reasonable option. The larger the number of providers operating within an area, the faster the consumers can get connected. Finally, the last remark justifies our choice of wireless spots as a supplementary network accessibility measure. A recent explosion of wireless technology requires huge equipment investments. Therefore, a wide Wi-FI coverage obviously shifts territorial attractiveness. Consequently, we record the number of wireless spot within a department, making distinction between for free and for fee access points. To quantify network accessibility factors, we construct, in the same way as before, the composite index of network accessibility. Scalar morphing of France departmental regardless the network accessibility index is depicted in the Fig. 9.

-Insert Figure 9 here-

Once again, hypertrophic character of departments lying within the capital region (Ile-de-France) is extremely well pronounced. Second best score is recorded by Rhine and Alps' departments. It is due to a recent liberalization of internet access in this area. Eastern departments also show good accessibility, outperforming Ain, Aveyron, Ariège, Vosges and Côte d'Armor departments.

Final cartogram In order to get the final picture of broadband network quality in France, we proceed with building a cartogram based on our quality and accessibility indexes described back in the previous paragraph. However, we do not simply sum them up, because the equal weighting of, for instance, effective bandwidth and Wi-Fi spots access would, undoubtedly blur the cartographic presentation. That is why, we have weighted each network quality feature in the following way:

- uploading bandwidth: 4
- bandwidth loss: 4
- number of services available within a line: 3
- number of internet carrier companies: 2

- unbundling rate: 2
- Wi-Fi spots coverage: 1

Recall that any French household can be connected to the internet network, but the bandwidth associated with a given offer varies considerably. That explains the maximum weight we have attributed to bandwidth and its loss. We have also considered the number of services available quite important, carrying less for competition factor (internet providers) and comfort factor (wireless spot access).

-Insert Figure 10 here-

The final network quality cartogram (Fig.10) brings some interesting insights. First, capital region as well as Rhine and Belfort departments are unquestionably the leaders; followed by some well performing departments, like Gironde, or Hute-Garonne. Unfortunately, there are many underdeveloped departments (Central and North-Western part of France), testifying the existence of numerical divide in France.

V Public policies related to broadband network development

In previous sections we have presented the state of broadband network development in France, which is far from being homogenously spread trough the national territory. At this point, we shall complete this picture by discussing a following policy question: are French public authorities interested in raising territorial attractiveness by developing broadband network in areas abandoned by commercial carriers? Although the quick response is yes, it requires some clarifications.

Since 1998 the telecommunication sector has been successfully opened to competition in France. This milestone step has not only enabled the entry of new telecommunication services providers, but also simplified the legal framework for local public authorities, allowing them to establish their own independent telecommunication networks. Moreover, the new 2004 "local government law"[12] has enabled local authorities to serve the commercially unprofitable segments of the market in the interest of satisfying a "universal service" objective. Since early 2000, this new legal framework has been playing a strong incentive role, facilitating huge public investments in telecommunication infrastructure at local level. More precisely, local authorities have created "Public Initiative Network", inspired and coordinated nationwide by the ARCEP (French regulatory authority of telecommunication sector) and aiming at establishing and operating (if needed), of modern broadband network. French local communities have been eagerly participating in the "PNI" focusing on threefold objective. First, further unbundling of historical telecommunication carrier's network initiated

[12] "Public Network Initiatives" under the provisions of sections of "Code Général des Collectivités Territoriales" L1425-1 (2004)

by public authorities should increase the competition among other providers. Moreover, public authorities go between France Telecom and other carriers in fiber leasing procedure. Thus, new operators not only have access to efficient infrastructure but can also diversify their offer (DSL TV, etc.). Second, covering of the "white zones" with Wi-Fi, WI-Fi Max or satellite internet access should make the internet-excluded part of population benefit from new technology. Third, local authorities consider extremely important to guarantee high-speed internet access to companies. In reality, the numerous local small business and/or industrial parks have been neglected by broadband providers. Therefore, public investment is essential in tooling up of industrial zones, which in turn, raises their attractiveness. Finally, local governments have judged necessary to upscale bandwidth and to offer the FTTH fiber internet access available to all.
The "PNI" projects are the most frequently established as PPP, which is usually associated with more efficient use of public funds and leads to a speedier completion of works. It also strengthens competition in the field, because the creditworthiness and reliability of public business partners plays a strong incentive role. By the end of 2008, there were 119 "PNI" projects valued at €1.4 billion (nearly a half of this amount brought by private investors); 56 among them were ready to commercialize at that time. Figure 11 depicts geographic dispersion of project and shows their development phase.

-Insert Figure 11 here-

Red areas on the map mark yet operating projects. Compared to the broadband network quality and accessibility cartogram presented in the previous section, we notify a continual improvement in the case of white zones in central part of France. However, some territories (Loire region) are still lagging behind (white zones on the map stand for areas in which PNIs are at preliminary conception level). Nevertheless, 2009 ARCEP PNI assessment-related report reveals that local engagement in providing broadband infrastructure got rid of 80% of white zones. Moreover, thanks to local efforts 40% more lines have been unbundled compared to what would have been done without public intervention. The ARCEP report also states that fiber switching rate among companies is 10 times higher within a PNI zone and that final consumer's price for an internet offer has been decreased by 20 to 50%.

VI Concluding remarks

The "digital divide" is very complex to apprehend. First, the fragmentation of France is more consequential than it could seem in a sketchy analysis. Whereas an unipolar vector anamorphosis of France has demonstrated that the quality of the inter-territories telecommunication networks (upstream of the local loop) is homogeneous, a scalar anamophosis of France in an intra-territory approach, i.e. within territories, has permit to visualize a very differentiated quality of the local loop network for electronic communications. Thus, informational anisotropies do exist in France. Second, these anisotropies are multi-scales i.e. the "digital divide" is a multi-scale divide. Third, private and public investments in the field of broadband infrastructure, particularly those induced by local authorities, , create very complex informational anisotropies and probably, as a consequence, economic anisotropies in France, between "départements" and within "départements". Additionally, the analysis in terms of industrial organization is not able to explain these anisotropics; neither does an institutional analysis of the regulation of "info-communications industry". Therefore, local authorities play a determinant role through their investments. Moreover, public investments in infrastructure influence themselves in terms of economic development because of the technical superposition of the different types of technical networks (transport, electricity, telecommunication) induced by structures of network's industries. Finally, it is necessary to transpose our tools (cartograms) to other territories and other infrastructures in order to confirm or reject these concluding remarks in a more general context.

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Appendices

Figure 1: World population map (2000)

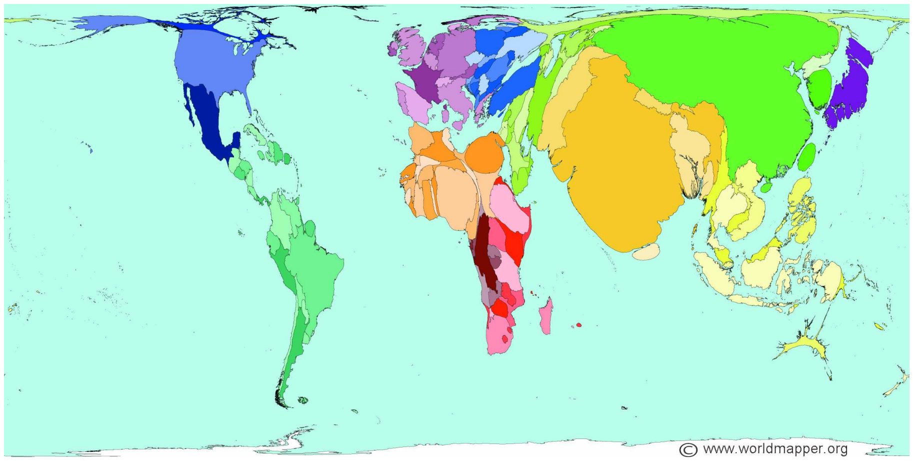

Figure 2: France transformed by hi-speed train (TGV) network (2007)

Figure 3: Fiber optic network in France (2005)

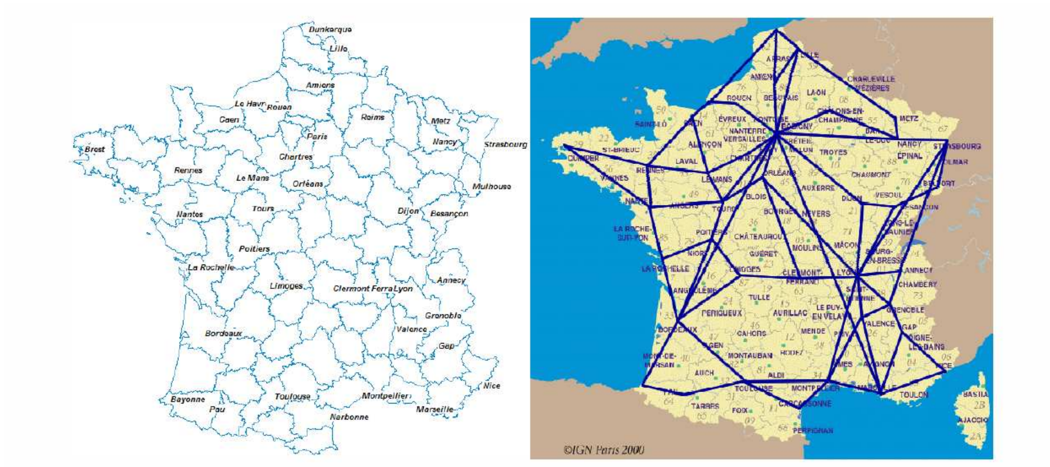

Figure 4: Fiber optic network in France (2005)

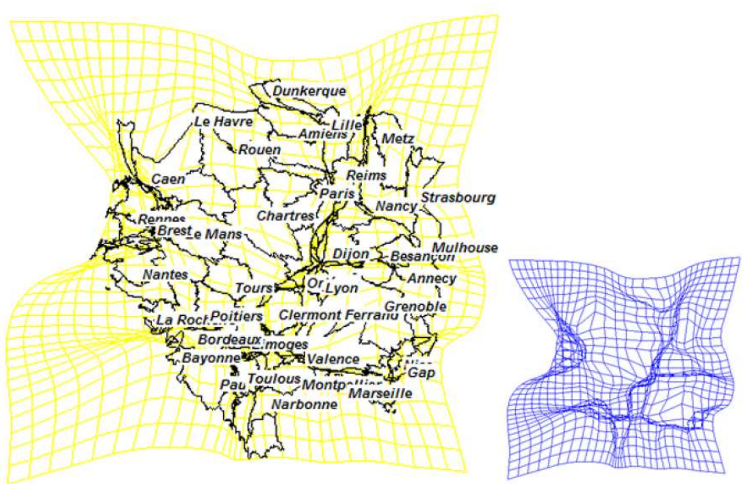

Figure 5: France transformed by the "Informational distance" (response time criterion)

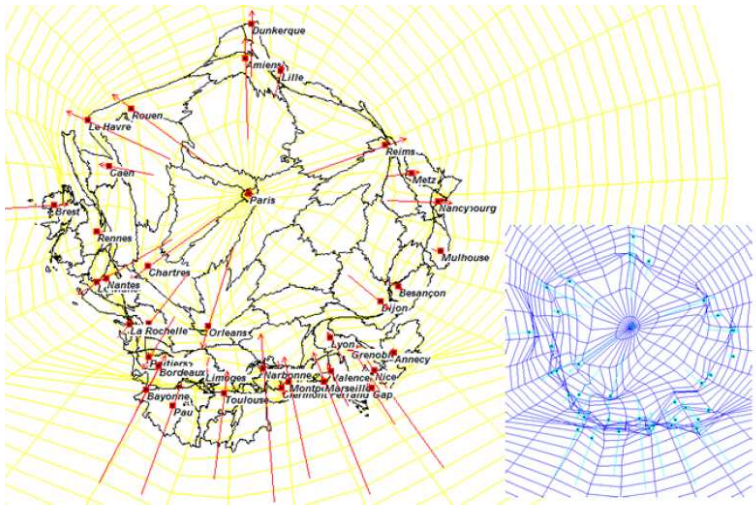

Figure 6: France transformed by the "Informational distance" (*"time to live"* criterion)

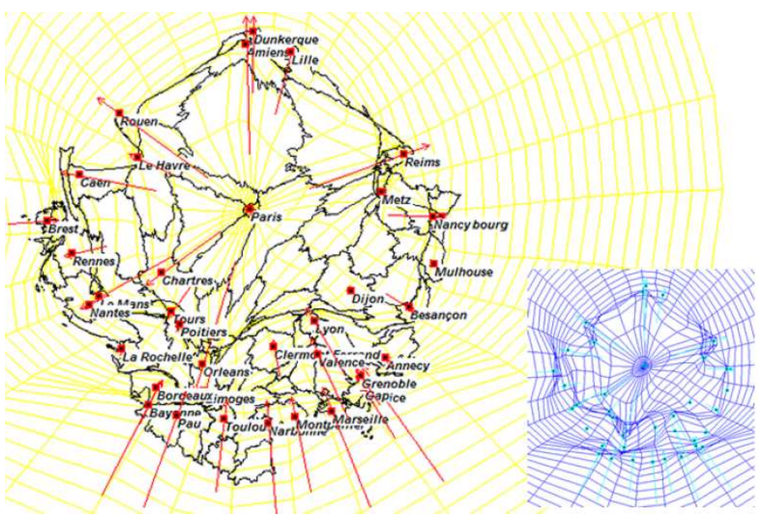

Figure 7: France transformed by the "Informational distance" (isochronic circles)

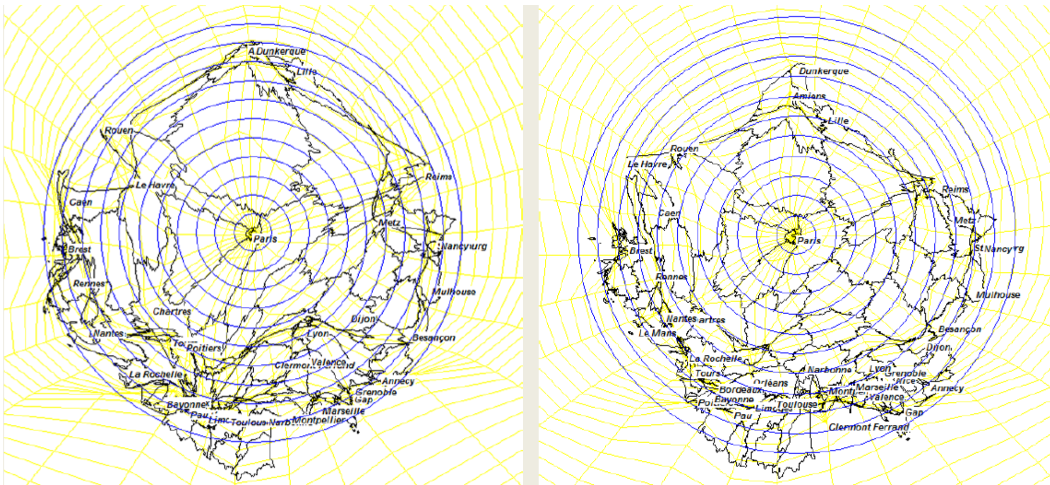

Figure 8: Quality dimension of France's broadband network

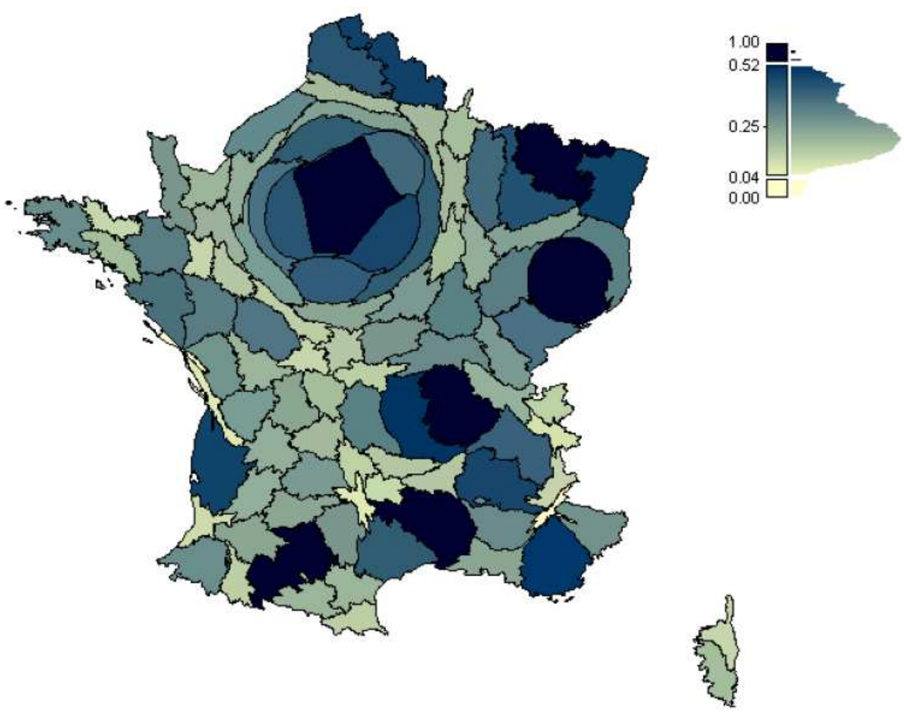

Figure 9: Accessibility of France's broadband network

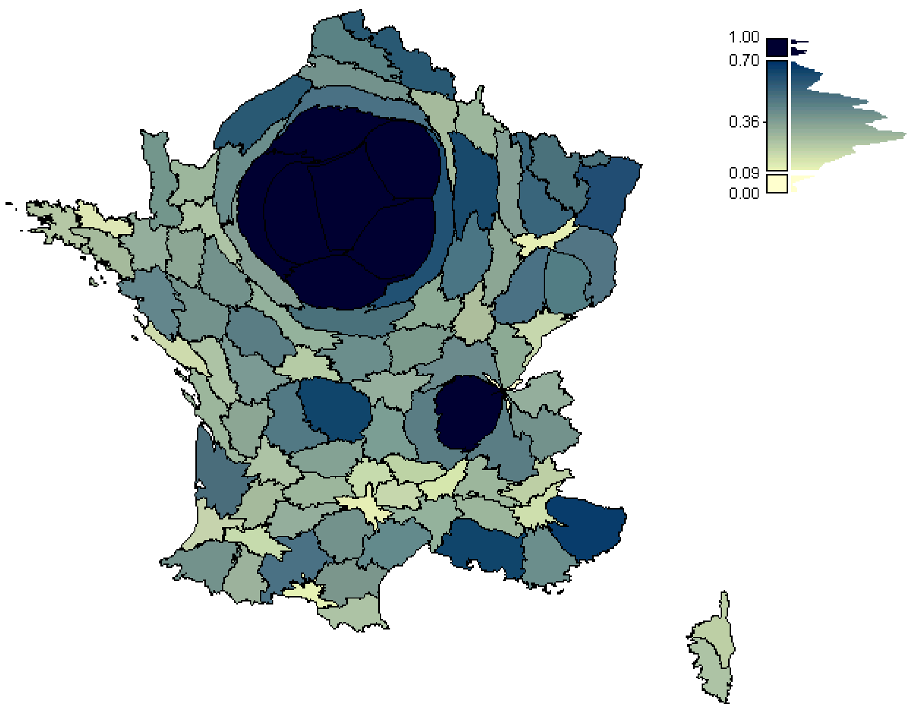

Figure 10: Overall quality and accessibility dimension of France's broadband network

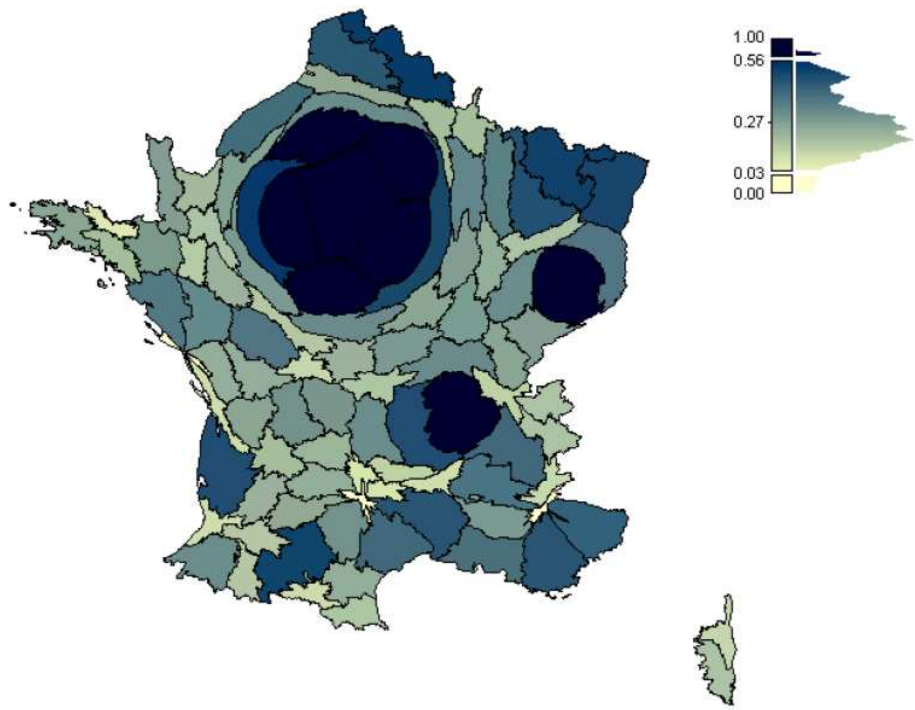

Figure 11: “RIP” projects in France by December 2008