Spatial structure and mobility patterns: towards a taxonomy of the Italian urban systems

by

Andrea Cirilli

Ph.D. student in Economics at the Dept. of Economics

Università Politecnica delle Marche (Ancona - Italy)

e-mail: a.cirilli@univpm.it

and

Paolo Veneri

Ph.D. student in Economics at the Dept. of Economics

Università Politecnica delle Marche (Ancona - Italy)
e-mail: p.veneri@univpm.it

Abstract

Urban spatial organization has become a wide field of research in the last years, since it is thought to be an important determinant of the city's performance, from many points of view. Nevertheless, Italian urban spatial organization has not been studied in depth yet and a general description of the Italian urban territory is lacking. The aim of this work is to build a taxonomy of the Italian cities – where the latter are conceptualised as agglomeration of contiguous municipalities – on the basis of their spatial organization features and of their patterns of commuting-to-work mobility. To reach this aim, three preliminary steps had to be carried out. First of all, the major Italian urban systems have been identified following a functional approach that is based on the principle of maximum self-containment of commuters' flows, as allowed by Local Labour Systems (LLSs). Secondly, original indicators have been built to gain a better understanding of cities' spatial organization and of their patterns of mobility. Thirdly, the relation between these two dimensions has been investigated through a multivariate statistical analysis. The results of the analysis show that spatial organization – especially urban dispersion – and mobility patterns are closely related and cities might be aggregated in five groups, ranging from the most compact and transit-oriented cities to the most dispersed and car-oriented ones.

Spatial structure and mobility patterns: towards a taxonomy of the Italian urban systems[*]

Andrea Cirilli[§] and Paolo Veneri[§]

1 Introduction

Urban spatial organization has become a wide field of research in the last years, since it is thought to be an important determinant of cities' performance from many points of view. First of all, the spatial structure of a city both affects and is affected by the type and intensity of social and economic interactions among individual agents – households and organizations. Depending on how these interactions are shaped and how frequent they are, different external economies may arise – to different extents. These economies, in turn, may have an impact on the city's ability to generate innovation and development through a process of collective learning.

Secondly, the way in which a city is spatially organised influences the quality of life, depending on the types of residential and productive settlements that prevail as well as the level of consumption of scarce territorial resources, such as land, energy and even time.

Thirdly, urban spatial organization is also connected with the way in which people travel across the city. This can affect the patterns of mobility at the urban level, which tend to reflect the *circadian cycles* that people usually undertake during their daily activities (e.g., work, study, shopping and leisure). In this perspective, information about commuting flows is quite useful, since it tells us about the duration and transport mode of home-workplace and home-school commutes within an urban system.

This work aims at describing the patterns of mobility within the (major) Italian urban systems. In this explorative analysis, the spatial organization of the systems will be examined as well, following a quite prolific field of study that has widely investigated the relationship between spatial structure and mobility patterns at the urban and especially at the metropolitan level[1]. This type of analysis appears to be rather relevant on both positive and normative grounds. In Italy, indeed, commuting patterns have not been studied in detail so far, especially in a comparative way[2]. An exploration of the work commutes within functional urban systems

[*] This work is part of a wider research project on the Italian urban systems. The project has been developed by the research team *UrbAnLab* and is co-ordinated by Antonio G. Calafati at the Department of Economics – Università Politecnica delle Marche (UPM), Italy.

[§] Ph. D. student in Economics at the Department of Economics – UPM. Despite being a common work, sections 1, 3.2, 4.2, 4.3 and the Appendix can be attributed to Paolo Veneri, while sections 2, 3.1, 3.3, 4.1 and 5 to Andrea Cirilli. The authors wish to thank – without implicating – Elvio Mattioli and Riccardo Lucchetti for their valuable comments and suggestions.

[1] See among others Cervero (1996; 2002) Stauffacher *et al.* (2005), Newman and Kenworthy (1991), Frank and Pivo (1994), Giuliano and Narayan (2003). Classical studies on urban form can be found in Jacobs (1961) and Lynch and Rodwin (1958).

[2] A notable exception, in Italy, is the work of Camagni *et al.* (2002) on the metropolitan areas of Milan and Brescia as well as those of Camagni and Travisi (2006) and Camagni *et al.* (2006) on the provinces of Turin, Padova, Florence, Perugia, Naples, Potenza and Bari.

across the whole Italian territory, therefore, may allow finding some interesting stylized facts. Such facts, of course, would then be a new starting point in an interpretative effort, aimed at understanding why commutes take a certain shape and how that can be put down to the spatial structure and dynamics of the urban systems.

In a normative perspective, moreover, an analysis of the mobility patterns in terms of commuting-to-work flows appears to be quite meaningful and instructive nowadays, given the growing attention that has being paid to the implications of urban dispersion – and of the type of mobility associated with it – in terms of economic, social and environmental costs[3]. It is beyond the scope of this work to identify and possibly gauge such costs. It is worth keeping in mind, though, that local communities have to bear different types and levels of costs depending on the way and the intensity with which a city expands – as well as on the shape that mobility takes within it as a result[4].

The paper is organized as follows. In paragraph 2 a brief review of the concept of urban dispersion and of its determinants is proposed, from both a theoretical and a historical point of view. In paragraph 3 the Italian urban systems are described, introducing some relevant variables that relate to both their spatial organization and the patterns of mobility within them. In paragraph 4 a factor analysis is carried out in order to gain a better understanding of the relationship between the spatial structure and the mobility patterns in the Italian urban systems. The ultimate goal is to build a preliminary taxonomy through a subsequent cluster analysis. In paragraph 5 some concluding remarks are made.

2 Sub-urbanization and urban dispersion

2.1 Some historical trends

The archetypical (compact) city, as conceptualized by Weber (1950), is densely inhabited, with a distinct identity, a large variety of social and economic functions and a high density of relationships based on proximity. In such a city the public transport system tends to be rather widespread and usually plays a relevant role. In the last decades, however, a continued process of decentralization – of both residential and economic activities – and an increasing imbalance between urban spatial expansion and underlying population growth have led a large number of researchers to investigate the urban sprawl issue. Following Brueckner (2001,

---

[3] See for instance Altshuler (1997), Anas *et al.* (1998), Ewing *et al.* (2002), Muñiz *et al.* (2006) and Tsai (2005) for the US; Pouyanne (2006) for the case of Bordeaux and Salatino (2006) for Europe; Calafati (2003), Camagni (2002), Camagni *et al.* (2006), Camagni and Travisi (2006), Lattarulo (2003) and Salatino (2004) for Italy.

[4] It is indeed debatable whether the compact city is more efficient than the dispersed city in both a static and dynamic perspective, and the debate is still quite lively. Besides many sprawl critics, in fact, lots of scholars have studied the compact city and the market failures that it is subject to. See for instance Dubois-Taine and Chalas (1997), Gordon and Richardson (1997) and Camagni *et al.* (2002).

pp. 65-66), urban sprawl can be thought of as a process of urban spatial expansion that appears to be more intense than it is socially desirable. In other words, the key issue here is not just the natural spatial growth of cities that follows the increase of population and of its material well-being (i.e., more and larger houses are needed), but the very fact that this growth often tends to be too rapid and too intense from the social welfare point of view.

The dispersed city that is emerging as a result of such processes of decentralization and urban dispersion is basically a low-density city, where land consumption is high but discontinued and where the new settlements tend to specialize in either residential or productive activities. Even in the latter case, specialization tends to be higher in a given sector, rather than quite even among different sectors. Wholesale commerce, low-scale manufacturing industry and routine tertiary industry are more likely to be found in the suburban districts of a dispersed city, as well as leisure centres that contain cinemas, restaurants and other recreational venues. The dispersed city strongly depends upon the automobile use, and it has often developed in the absence of (or anyway not in accord with) a strategic planning of the whole functionally integrated urban area. As a result, the new settlements have seldom developed along the lines of the major public transport infrastructure. Thus it happens that many residential suburbs or recreational centres sometimes are not easy to reach by public means of transport and require an intense use of motorize private means.

Looking at the U.S. experience in a long run perspective, it turns out that cities have been gradually spreading out during the last two centuries. The growth and subsequent suburbanization of the metropolitan areas has taken place worldwide after World War II, although this tendency has been faster and more accentuated in the US (Mieszkowski and Mills, 1993, pp. 135-136).

The physical expansion of cities has been largely induced by population growth and economic development but can be also put down, to some extent, to a process of decentralization mainly due to sequences of innovations in the transportation and communication fields. As Anas *et al.* (1998) point out, prior to 1850 both productive and residential activities tended to concentrate in the urban core, where the main transport nodes (a harbour or other waterways and – later in the century – rail terminals) were to be found. Scale economies in the freight processing, inefficient freight and personal transport means within the city and – finally – the high cost of intra-urban business communication, prevented at that time firms and households from spreading out in the surroundings[5].

After 1850 and – to a larger extent – in the early 20th century major innovations in both freight and personal transportation and other relevant changes in the communication technologies fostered a process of decentralization that, according to the authors, has been

[5] Another historical explanation of the role of transport innovations in the suburbanization process and in the out-migration of the affluent can be found in Le Roy and Sonstelie (1983).

continuing for a couple of centuries, providing a case for the so-called *urban sprawl* – though in the recent decades the decentralization process has taken a more polycentric form (Champion, 2001).

At different points in time technological progress has kept giving impetus to urban decentralization. Recently, indeed, the rapid evolution of ICTs, as well as the progressive shift towards an ever more tertiary and internationalized economy, have dramatically modified the way the production processes are organized (Anas *et al.*, 1998). Firms, in both the industrial and in the services sector, often resort to part-time and flexible work, and tend to de-locate their routine activities outside the Central Business District (CBD) and quite far away from their Head Quarters (HQ), so as to take advantage of lower labour costs and lower urban rents (and often of fiscal incentives as well). The spatial dispersion of the productive activities, indeed, has become possible thanks to the intense use of advanced telecommunication and information technologies, which allow direct control and co-ordination of such activities from the HQ (Sassen, 1994). Vertical disintegration and territorial delocalization of (routine) productive processes often entail the development of productive (and commercial) strips outside the city core, which tends to expand home-work mobility and freight transport between firms.

2.2 Theoretical background

Urban sprawl has been more intense in the last decades, and has been fostered by both economic and institutional factors. Economic development, to begin with, has long played a relevant role in the historical evolution of urban spatial structure. Increases in income, wages and purchasing power – especially during the last five decades – have enhanced the material well-being of the households and have progressively changed their lifestyles and housing preferences (Camagni *et al.*, 2002). In other words, households – especially younger working adults – could gradually afford to buy and use (and gradually developed a preference for) private motorized means of transport, the automobile *in primis*, which allow faster and more comfortable journeys, more privacy and the opportunity to arrange one's movements more freely. As households have grown more affluent, hence, they have increasingly sought larger accommodation, preferably outside the central city – where air and noise pollution, as well as congestion and urban blight have in some cases reached intolerable levels. Increases in income and evolution of lifestyles have modified housing preferences. Middle-income households, indeed, have increasingly preferred living in suburban and less congested areas, where they can organize their circadian cycles through their private automobile and where they can often afford accommodations with a garden and/or some natural *amenities*[6].

The gradual shift of middle-income households towards the outskirts has also been fostered indirectly by a crowding-out effect that often comes into play in the central cities. Basically, high value added tertiary activities are able to pay higher rents and as a consequence are able to win central and convenient locations to the detriment of middle- and lower-income households. This effect is also compounded by the desire, on the part of upper-income professionals, to live in a *consumer city*, where a large array of high quality cultural and recreational services is on offer (Glaeser, 2001).

Some economic factors are related more closely to other economic agents than the households, and namely the firms and the building contractors. Firms, for instance, often find lower localization costs in the suburban areas, which are particularly convenient for those activities (i.e., back-office and routine activities) that do not require a direct access to the CBD and to its advanced and diversified services. From their point of view, moreover, central sites are difficult to reach by cars and trucks, which have increasingly become a more efficient and reliable means of freight transport. In addition, new models of commercial offer in the suburbs have developed that require the use of the automobile. Finally, the spreading out of the residents has implied a corresponding spreading out of the workforce, and firms may find useful to locate where the latter is most easily available (Hoogstra *et al.*, 2005). As Brueckner (2001, p. 71) points out, job delocalization has partly resulted from the residents' suburbanization but it has also been determined by firms' preference for truck transport and lower-cost suburban locations (which often have a easier highway access too).

Building contractors, instead, often realize that revitalization of the real estates in the historical central city is costlier than new building construction in the suburbs, where they also find fewer institutional constraints and have the chance to provide a more diversified residential offer.

As regarding the institutional factors, here are briefly mentioned the following. First of all, a rapid process of city planning deregulation in the last two decades has resulted in fewer environmental and administrative constraints when it comes to investing on new urban settlements. Secondly, fiscal policies at the municipal level often turn out to be rather short-sighted. In particular, neighbouring municipalities may sometimes engage in a selfish competition in order to attract real estate investments. As a consequence, some policy tools – like real estate taxation and urbanisation burdens – are sometimes used inappropriately and land use decisions may be distorted, with serious consequences in terms of central city decay or functional and social segregation (Camagni *et al.*, 2002). Finally, there is often an imbalance between the official level of political regulation and the actual level of social and

[6] Actually, a decentralized process of urban development – characterized by low-density and scattered new settlements – may result in the interruption of the rural and natural continuum (Camagni *et al.* 2002).

economic self-organization of the territory. In Italy, in particular, although municipalities are in many cases functionally integrated in larger urban systems, governance at the level of the functional urban area is generally lacking or insufficient (see below).

It is now worth looking at the determinants of urban dispersion in the light of relevant economic theory, so as to gain a deeper understanding as to why low-density and discontinued urban development sometimes appears to be an ineludible process in the absence of appropriate regulation. As underlined above, an excessive physical expansion of cities – relative to what could be considered the social optimum – entails quite a large array of collective costs that the whole local communities are bound to incur. These costs arise because of market failures and, in particular, because of externalities that private economic agents – in a free market environment – are not able to or do not find it convenient to take fully into account in their individual decisions. The presence of externalities, hence, tends to distort such decisions as those regarding transport mode, land use and residential or productive localization, leading private agents to a sub-optimal outcome. In other words, individual decisions may be rational *per se*, but may result in an irrational outcome if interaction among individuals is not co-ordinated by a public (collective) agent (Camagni *et al.*, 2002).

One market failure arises because of the underestimation of the value of open space (Brueckner, 2001). In a mono-centric city model framework[7], indeed, land rent and land consumption depend on the distance from the CBD, the commuting cost at that distance and the income of the residents. Also, urban and agricultural rents should be equal at the edge of the city. As the city expands physically, the social value of the vacant land beyond its boundary should incorporate not only the agricultural rent that it earns, but also the amenity value in terms of scenery, recreational and other open space benefits. Clearly, such benefits are not priced in the market and private agents do not value them in their land use decisions.

Another source of market failure can be found in the congestion externality (Anas *et al.*, 1998; Brueckner, 2001). This type of externality may affect the compact city too and may actually turn out to be even more severe in this case, when the bulk of commuting flows develop radially towards the CBD. As a private agent chooses to use a motorized private means of transport, she does not pay for her marginal effect on the congestion levels (i.e., the private cost of using one's own car is lower than the social cost). The unwanted consequence is an underestimation of the travel costs, which in turn leads to distortions in the land market, with too much central land being allocated to roads (Arnott, 1979).

Another market failure occurs when a new urban settlement is built. New housing construction, indeed, must be coupled with the provision of road and sewerage infrastructure, as well as by the supply of some essential local public goods (i.e., schools, parks etc.). Brueckner (2001) identifies the source of this failure in the financial markets. He points out,

---

[7] For a detailed and analytical illustration of the model see Alonso (1964), Mills (1967) and Muth (1969).

in particular, that under the typically prevailing financing contracts, the new homeowner bears an infrastructure-related tax burden that is systematically lower than the new infrastructure cost that she actually generates.

2.3 Specific Italian features

Urban sprawl has been studied in detail with regard to the US metropolitan areas and the process of suburbanization that they have undergone especially in the last decades[8]. This process has involved European cities as well, albeit in different forms and to different extents. Europe's urban landscape, however, presents an enduring polycentrism, thanks to its large number of long-standing cities, whose historical centres – albeit subject to decay to some extent –, still maintain a high level of attractiveness. They are characterized, indeed, by many cultural and architectural amenities. This helps explain why in Europe low-income groups are often expelled from the central areas, where an opposite – but less quantitatively important – tendency of *gentrification* takes place (Camagni *et al.*, 2002).

On the contrary, in North American metropolitan areas central cities tend to be occupied by the poor and ethnic minority groups, while middle- and upper-income classes are more likely to move farther out in the suburbs. Mieszkowski and Mills (1993, pp. 136-138) explain this tendency referring to the fiscal-social problem of central cities, in that the latter are often fraught with high taxes, poor public goods, racial and social strain, urban crime, congestion and poor air quality. This is why the affluent prefer moving out in the suburbs, trying to develop homogenous communities of residents of like income, educational and race. As the affluent leave the central cities, a self-reinforcing process sets in motion: the central areas are subject to further degradation and to an ever more severe budget problem. By contrast, the establishment of income-stratified communities with high quality schools and public services in the suburbs attracts more affluent and well-educated households, while local redistributive taxes to the benefit of the poor can also be avoided in such homogenous communities (and the entry of lower-income households can be prevented through land use controls like, for instance, a minimum lot size).

In Italy a new wave of urbanization took place in the Fifties and the Sixties, induced by a late (but rapid) industrialization process. At that stage larger cities represented the preferential location for industrial firms (Bertuglia *et al.*, 2002). A turning point was reached during the Seventies, because of technological innovations in the transport and telecommunication sectors and a general deregulation process in urban planning. These innovations induced firms to locate in the city surroundings. Likewise, households – also taking advantage of higher incomes – began to move outward in the suburbs. From that decade onward, however, residential and productive activities have expanded beyond the central cities in a scattered

[8] Ewing (1997); Galster *et al.*, (2001).

way (Mela, 2002), while in the previous decades cities tended to develop – from the spatial point of view – by contiguity. This tendency slowed down in the Nineties, when there was a wave of urban policies aimed at revitalizing the historical centres, which still appear to be the preferential location for advanced tertiary activities and immigrants' commercial enterprises[9]. Nonetheless, a decentralization process is still noticeable, though it mainly concerns commercial and leisure centres as well as universities (Davico, 2002). In other words, the supply of *some* services that were typical of the central cities is now decentralized in the emerging suburban areas.

Italy, in addition, is characterized by a long-standing tradition of municipalities that claim plenty of autonomous functions. These municipalities in many cases are very small and anyway represent an inadequate level of administrative governance if compared to the actual level of social and economic self-organization of the territories. Urban spatial development, indeed, has often taken the form of a *coalescence* process. This process has resulted in the progressive (functional) integration of separate municipalities (not necessarily of relevant size) that have turned out to work together as a system (Calafati, 2003). This integration has been possible because of increasing relational densities among the municipalities, which, although spatially (and politically) separated, have found out to be increasingly linked to one another. Coalescence may have stemmed not only from the expansion of the original localities, but also from the formation of new settlements that have gradually filled the gaps between separate municipalities, outlining the border of a new (dispersed) city.

In Italy, then, the discrepancy existing between the actual level of self-organization of a system – what can be seen as a *city in nuce* (Calafati, 2005) – and the level of governance is more accentuated than in other European countries. From a political and institutional point of view, indeed, local systems that are *de facto* emerging as cities are not recognized as an autonomous level of governance[10].

3 The Italian urban systems

3.1 The units of analysis

This work focuses on 111 Italian urban systems. The identification of these systems relies upon the definition of the *Local Labour System* (LLS) proposed by the Italian Statistical Office (Sforzi, 1997). A LLS, indeed, is defined as a cluster of contiguous municipalities that are functionally integrated. This approach resorts to a principle of commuting-to-work flows self-containment in order to identify a functionally integrated system. Clearly, functional

[9] This may suggest that a segregation problem exists in the central cities and in their historical centres in particular.

[10] The national government, however, has recently started to identify the metropolitan areas as relevant units of local governance, at a level that is above the municipality and below the province and the region. Nevertheless, coalescence processes in Italy have concerned many small and medium scale systems as well.

integration involves also other features, such as self-containment of students' flows and other flows that take place for consumption or recreational purposes. Furthermore, a system is integrated when its internal organization relies upon a set of shared infrastructure (e.g., airports, railway stations, commercial centres that actually serve a wider area than that where they are located etc). Despite being a rough approximation, the choice of LLSs may be a good starting point in the identification of functionally integrated local systems for the purpose of this work. Among all the 686 Italian LLSs, only 111 have been selected. In particular, the analysis has been narrowed to those systems that may be conceptualized as *urban* systems (i.e., those local systems whose pivotal municipality had at least 50,000 inhabitants in 2001[11]). Again, the very urban nature of a local system should be investigated more thoroughly, but this may be an acceptable simplification for the purpose of this work.

In the following tables the territorial distribution of the urban systems is shown (Tab. 1), while emphasis is also placed on those systems that might be interpreted as *metropolitan areas*[12] because of their population size (Tab. 2). One may note that the largest group can be found in Central Italy (39 cities), though Southern Italy and the Islands, taken together, account for 44 cities out of 111. As for population size, 15 metropolitan areas – that is urban systems with more than 500,000 inhabitants in 2001 – can be identified, but the number rises up to 19 if a 400,000 population threshold is applied.

Tab. 1 Territorial distribution of the 111 urban systems by region and macro-area

Region		Macro-area	
Liguria	4		
Piemonte	5		
Lombardia	9	North	28
Trentino Alto Adige	2		
Veneto	6		
Friuli Venezia Giulia	2		
Emilia Romagna	13		
Toscana	12		
Marche	4	Centre	39
Umbria	3		
Lazio	4		
Abruzzo	3		
Molise	1		
Campania	9		
Basilicata	2	South	28
Puglia	11		
Calabria	5		
Sicilia	14	Islands	
Sardegna	2		
Italy	111	Italy	111

Source: our elaboration on Istat Census data

[11] Italian population was 56,979,516 in 2001. The 111 urban systems concentrated, in the same Census year, 34,320,804 inhabitants, hence accounting for 60.2% of national population.

[12] By "metropolitan area" here is meant an urban system – a LLS – whose population size is higher than a given threshold. Obviously a more accurate definition would involve other considerations on both economic and institutional grounds.

Tab. 2 The largest urban systems in terms of population size (2001)

Urban system	Population
Rome	3,374,511
Milan	2,975,754
Naples	2,235,602
Turin	1,684,336
Palermo	856,152
Genoa	723,633
Bologna	723,366
Florence	705,872
Bergamo	677,196
Venice	604,356
Bari	600,549
Catania	580,466
Padova	565,262
Busto Arsizio	562,322
Verona	540,753
Cagliari	461,160
Taranto	453,107
Como	408,746
Brescia	407,887

Source: our elaboration on Istat Census data

3.2 The variables

This work consists in a preliminary analysis of the Italian urban systems in terms of spatial structure and mobility patterns. On describing the spatial organization of the major Italian cities, four dimensions of urban form have been considered, following the approach in Tsai (2005[13]).

First of all, one should look at the sheer *size* of an urban area. The most obvious way to measure the size of a city is by considering its population. When it comes to assessing the degree of urban dispersion of a given city, however, the land area of the system may turn out to be a more appropriate measure, under the assumption that land consumption is higher in more dispersed cities. Nonetheless, land consumption also increases as a result of population growth. Tsai (2005) then suggests that land area may capture the metropolitan dimension of a system rather than its degree of urban systems. In this work, however, population is likely to be a more appropriate proxy for the metropolitan dimension of the systems, given that the latter are actually LLSs and may in some cases include rural or marginal areas in their territory[14].

A second spatial dimension can be associated with residential density, which appears to be a very simple and sound measure of urban dispersion. More sophisticated variations of this

[13] Tsai's approach has actually been applied to large US metropolitan areas. One should be cautious, hence, when it comes to carrying his measures over to the Italian experience and to the Local Labour Systems, whose very urban and metropolitan nature is sometimes questionable. Still, Tsai's approach appears to be rather meaningful and a few useful insights into the Italian urban landscape can be derived anyway.

[14] It is worth reminding that the LLSs are identified on the basis of a functional integration criterion, and no explicit measures are taken into account in order to assess the urban (or metropolitan) dimension of the systems.

measure have been proposed, most of which have actually turned out to be highly correlated with density itself and hence do not necessarily add much in empirical analysis. In this work, the following variables have been computed that can be grouped together as *intensity-based* proxies for urban dispersion:

- gross residential density, that is residential population over total area (in square kilometres) in 2001 (*density*). This variable has also been re-scaled in log terms (*ldensity*) for comparability purposes. The higher this variable, the more compact the system.
- Residential structure, that is the share of population living in "inhabited settlements" and "dispersed houses" over population living in "inhabited centres" in 2001 (*sprawl*) – according to Istat classification. The higher this variable, the more dispersed the system
- Rural share, that is the share of total agricultural farms' area in 2000 over total area in 2001 (*rural_share*). The higher this variable, the less urbanized the system.

Following Tsai (2005), information about size and density is not enough if one is to describe the spatial organization of an urban system. Two more dimensions, indeed, should be taken into account. One is bound to capture the degree of concentration of residential and economic activities within the territory of the system. In other words, given a certain average density, it may be the case that high-density sub-areas exist within the urban systems, as opposed to much less densely inhabited areas. Other systems, by contrast, may be characterized by a much more even distribution of either population or employment over their territory. In this work, the following concentration variables have been computed:

- pivot population share, that is the share of population living in the pivotal municipality over the total population of the system in 2001 (*pivot_pop_share*) The higher this variable, the larger the weight of the pivot on the system (which tends to be mono-centric in that case, as opposed to either a more dispersed or poly-centric system).
- Pivot employment share, that is the share of employed people in the pivotal municipality over the total number of employed people in the system in 2001 (*pivot_empl_share*). The higher this variable, the larger the weight of the pivot on the system[15].
- Population concentration, that is the Gini concentration index calculated as follows:

$$gini\_area\_pop = \sum_{i=1}^{n} |A_i - P_i| \qquad (1)$$

where A_i and P_i represent, respectively, the area and population shares in 2001 of the i-th municipality over the whole urban system, whereas n is the number of municipalities in that

[15] According to Istat, by "employed people" in a given city here is meant the number of people that have a job in that city but do not necessarily reside in it.

system. The higher this variable, the more concentrated the population distribution over the territory of the system.

- Employment concentration, that is the Gini concentration index calculated as follows:

$$gini\_area\_empl = \sum_{i=1}^{n} \left| A_i - E_i \right| \tag{2}$$

where A_i and E_i represent, respectively, the area and employment shares in 2001 of the i-th municipality over the whole urban system. The higher this variable, the more concentrated the employment distribution over territory of the system[16].

The concentration variables add relevant information to the basic intensity-based variables of urban dispersion but still they do not take into account the spatial relationship existing among the sub-areas of a given urban system. In other words, if a system is characterized by the presence of some high-density sub-areas within its territory, it is not clear whether these sub-areas are actually grouped together – as it is the case in a more polycentric and organized system – or randomly distributed – as it happens in a purely dispersed system, where urban sprawl is more accentuated.

Here comes the fourth dimension of urban form, which tells about the degree of clustering of sub-areas within the urban systems. The degree of clustering may be measured through the Moran and Geary indexes of spatial auto-correlation, once again based on either population or employment. It may be worth questioning, though, whether the definition of sub-area used in the empirical work (in this case the municipality) is suitable for the computation of such indicators. It may be the case, indeed, that a more appropriate definition of sub-area can be found below the municipal level (Census sections in the Italian experience, Traffic analysis zones in the US experience and so on).

Other variables are related to the functional diversity of the systems and to their spatial expansion:

- relative functional specialization of the pivot, that is the difference in absolute value between the pivot employment and population shares over the whole system in 2001:

$$pivot\_mix = \left| E_p - P_p \right| \tag{3}$$

where E_p and P_p are, respectively, the employment and population shares of the pivotal municipality in 2001. A positive value implies a higher proportion of productive activities in the pivot relative to the rest of the system. Vice versa, a negative value implies a higher proportion of residential activities in the pivot relative to the rest of the system. A zero value implies the same proportion of productive and residential activities in the two territorial

[16] See previous footnote for the Istat definition of employment.

scales. The difference is then taken in its absolute value: in this way, as the variable comes close to zero, functional diversity of the pivot is higher.

Two considerations should be made: this variable is intended to capture the relative *mixité* of the pivotal municipality, distinguishing between two broad functional destinations in land use: residential vs. productive. Second, the sheer share of employed people over the total population of the system – a traditional proxy of functional diversity – may not be informative at the SLL scale. Such a variable, indeed, would average the different functional specializations of the different municipalities within each system. Our variable, instead – albeit rough – may capture some features of the internal organization of the system. For instance, a city with a pivot highly specialized in productive functions is likely to be characterized by intense commuting flows along a radial way.

Functional diversity could be also be evaluated at the whole urban system level, by computing a Gini concentration index. Recalling the definitions 1) and 2), in this case the index takes the same shape but the relevant shares are those relating to population *and* employment.

As regarding the urban dynamics of the systems, the following variables have been considered:

- house age, that is the share of houses built after 1982 over total houses in 2001 (*house_age*). The higher this variable, the more rapid the urbanization process in the last decades;
- population variation, that is the relative population variation in the 1981-2001 period. The higher this variable, the more dynamic the urban system.

All these data have been drawn from the Istat Population Census (2001; 1981-2001) except for those regarding the number of employed people (Istat Industry and Services Census, 2001) and the total agricultural area (Istat Agricultural Census, 2000).

Besides all these measures of spatial organization and urban dimension, the focus of the analysis is also on mobility patterns. In particular, some variables have been built looking at the commuting-to-*work* flows *within* each urban system. Hence, all home-school flows have been ignored as well as those home-workplace flows between municipalities belonging to different urban systems. The variables relating to the mobility patterns have been computed drawing on the Istat Population Census (2001) and are the following:

- public transport share, that is the share of commuters-to-work that use public means of transport over the total number of commuters-to-work in 2001 (*public_share*);
- weighted average public commuting time, that is the average commuting time (in 2001) when public means of transport are used – times are weighted by the number of commuters:

$$average\_pu\_time = \frac{\sum_{i=1}^{n} \sum_{j=1}^{4} t_j pu_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{4} pu_{ij}} \quad (4)$$

where pu_{ij} are the public transport users in the i-th municipality whose commuting time is j, while t_j is the commuting time in minutes[17].

- Weighted average private commuting time, that is the average commuting time (in 2001) when private means of transport are used – times are weighted by the number of commuters:

$$average\_pr\_time = \frac{\sum_{i=1}^{n} \sum_{j=1}^{4} t_j pr_{ij}}{\sum_{i=1}^{n} \sum_{j=1}^{4} pr_{ij}} \quad (5)$$

where pr_{ij} are the private transport users in the i-th municipality whose commuting time is j, while t_j is the commuting time in minutes[18].

- Normalized average public transport time, that is the weighted average commuting time (in 2001) when public means of transports are used (as calculated above), normalized by the log of the total area of the system (*public_time*).

This normalization can be useful because commuting times do not necessarily reflect physical distances. The same average commuting time, indeed, may be observed in urban systems of different size, where average commuting distances can be expected to be obviously different. Hence a high commuting time may imply either a long commuting distance or a relatively inefficient (or over-crowded) transport infrastructure. The choice of a log transformation of the area has been confirmed by a Box-Cox regression[19]. Finally, other two variables have been considered:

- normalized average private transport time, that is the weighted average commuting time (in 2001) when private means of transports are used (as calculated above), normalized by the log of the total area of the system (*private_time*);
- private transport intensity, that is the share of commuters-to-work that use motorized private means of transports over the total employment of the system (*priv_intensity*). The higher this variable, the larger the share of commuters that use "less sustainable"

[17] Commuting times, in Istat Population Census, are classified into 4 categories: 0-15 minutes, 15-30 minutes, 30-60 minutes, 60 minutes or more.
[18] See previous footnote.
[19] See Appendix I.

means of transport, which are likely to worsen the problems of congestion and air and noise pollution.

3.3 Descriptive analysis

Before any attempt to identify (and interpret) the patterns of mobility and spatial organization of the Italian urban systems is made, it is advisable to compute some descriptive statistics, both at the whole sample and at the sub-sample levels.

Tab. 3 Summary statistics over the whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
area	111	773.3	531.1	50.0	3,657.0
population	111	309,244	486,286	55,542	3,374,511
density	111	466.6	520.8	61.2	3,956.8
sprawl	111	0.1025	0.0873	0.0063	0.4161
rural_share	111	0.6072	0.1759	0.1384	1.0470
pivot_pop_share	111	0.5546	0.1866	0.1343	0.9517
pivot_empl_share	111	0.6503	0.1755	0.1404	0.9742
gini_area_pop	111	0.3254	0.1462	0.0226	0.6956
gini_area_empl	111	0.4049	0.1663	0.0186	0.7650
pivot_mix	111	0.0973	0.0648	0.0004	0.2608
house_age	111	0.2115	0.0602	0.0460	0.4025
pop_var_81_01	111	0.0139	0.0476	-0.1025	0.1614
public_share	111	0.0496	0.0463	0.0036	0.2666
average_pu_time	111	25.59	4.46	16.16	43.51
average_pr_time	111	13.69	2.63	10.20	27.05
public_time	111	4.0121	0.6262	2.8300	6.0300
private_time	111	2.1462	0.3720	1.5415	3.5589
priv_intensity	111	0.5099	0.0715	0.2978	0.6310

Source: our elaboration on Istat Census data

Looking at the whole sample, some preliminary comments can be made:

- residential density shows a very high degree of variability – ranging from a minimum of 61 inhabitants per square kilometre to a maximum of almost 3,957 inhabitants per square kilometre. This is why a log transformation will be applied in order to compress the variation range of this variable and hence carry out a more appropriate multivariate analysis;
- on average commuting times are almost twice longer when public means of transport are used (25.6 vs. 13.7 minutes). Three possible reasons may help understanding this gap: 1) commuters tend to resort to the public transport system when they have to travel longer distances; 2) public means of transport are relatively less efficient and hence more time-consuming (regardless of the commuting distance); 3) public means of transport are used more intensely in larger systems, where distances are longer on average and also a congestion effect may come into play.
- given that the Italian urban systems widely differ in terms of total area (with a standard deviation of 531.1) and thus in terms of commuting distances that are

travelled within them, average commuting times have been normalized by the log of the area. In this way the element of physical distance within the systems is taken into account (a given commuting time in a very large system may not be comparable with the same time in a smaller system). Still, for the reasons discussed above, public commuting times are almost twice longer than private times, but are now more comparable among different systems;

- both the share of commuters that make use of public means of transport and – expectedly – the intensity of private motorized transport show a relevant degree of variability among the Italian cities, which makes it very interesting to study mobility patterns within them in more detail.

Given that we have considered a large array of different – though conceptually related – variables, it is necessary to look at the bivariate correlations (Tab. 4), so as to gain a better understanding of the relationships existing among them.

At this stage it is worth pointing out the following relationships:

- *public_time* and *private_time* are higher in more populated and densely inhabited systems, where public means of transport tend to be used more and congestion tends to be higher;
- the intensity of private motorized commuters is higher in dispersed and little concentrated systems (where congestion is lower and there are fewer incentives to use the public means of transport). As a result, when intensity is higher commuting times are lower (distances can be travelled faster in those kind of systems) and *public_share* is lower. Indeed in a dispersed city the public means of transport turn out to be relatively more inefficient (travel times are longer and the transport infrastructure is less widespread);
- the public share of commuting mobility is higher in more populated, compact and concentrated systems and is lower in more dispersed, rural or newly urbanized (i.e., dynamic in terms of population variation and house construction) systems;
- *house_age* is highly correlated with the population variation in the 1981-01 period and seems to capture some features of urban sprawl (i.e., it is higher in less concentrated, less compact, less urbanized and less functionally diversified systems);
- the higher the pivot population share, the more compact and less dynamic the system, and the more diversified the pivot;

Tab. 4 Bi-variate correlations among all the relevant variables

	area	pop	ldensity	sprawl	rural share	piv pop sh.	piv empl sh.	gini ar pop	gini area empl	piv mix	house age	pop var	public share	publ time	priv time	priv intensity
area	1															
pop	0.52**	1														
ldensity	-0.31**	0.49**	1													
sprawl	0.13	-0.25**	-0.46**	1												
rural_share	0.19*	-0.26**	-0.65**	0.35**	1											
pivot_pop_share	-0.16	-0.12	-0.15	-0.05	0.06	1										
pivot_empl_share	-0.06	-0.12	-0.26**	0.00	0.10	0.93**	1									
gini_area_pop	0.37**	0.23*	0.02	0.11	-0.04	-0.13	-0.08	1								
gini_area_empl	0.42**	0.20*	-0.09	0.17	0.02	-0.23	-0.08	0.94**	1							
pivot_mix	0.29**	0.01	-0.28**	0.15	0.09	-0.35**	0.01	0.15	0.41**	1						
house_age	-0.04	-0.16	-0.16	0.06	0.25**	-0.26**	-0.21*	-0.23*	-0.17	0.18	1					
pop_var_81_01	-0.10	-0.15	-0.06	-0.04	0.13	-0.24*	-0.23*	-0.22*	-0.22*	0.07	0.73**	1				
public_share	0.41**	0.69**	0.38**	-0.21*	-0.33**	0.05	0.09	0.38**	0.37**	0.10	-0.41**	-0.41**	1			
public_time	-0.05	0.47**	0.72**	-0.33**	-0.52**	-0.07	-0.09	0.07	0.02	-0.04	-0.06	0.00	0.49**	1		
private_time	-0.04	0.57**	0.79**	-0.36**	-0.65**	0.14	0.11	0.12	0.06	-0.11	-0.28**	-0.29**	0.64**	0.78**	1	
priv intensity	0.32**	0.06	-0.28**	0.12	0.06	0.08	0.12	0.13	0.13	0.08	0.03	-0.15	-0.02	-0.39**	-0.14	1

Source: our elaboration on Istat Census data

- the less diversified the pivot, the more dispersed and dynamic the system in terms of new house construction, though the correlations are rather weak.

Bearing in mind that our sample is rather large and heterogeneous, further descriptive analysis should be carried out before moving on. The 111 urban systems widely differ, if nothing else, because of their different size (in terms of both population and area) and different location (in terms of regions and macro-regional areas). Thus other summary statistics are presented at the sub-sample level, looking firstly at the macro-regional distribution of the urban systems (Tables A1-A4 in Appendix II) and, secondly, at their population scale (Tables A5-A8 in Appendix II).

From a territorial point of view, the following mobility patterns can be noted:

- the public transport share is highest in the North and lowest in the Islands. Consistently, the private motorized transport intensity is increasing from Northern Italy down to the Islands;
- commuting times with public means of transport do not vary much across Italy. Nonetheless, in the North – as well as in the Islands – higher values can be observed on average, while Central Italy shows a slightly lower value, evidence of a lower congestion of the cities in this area. A similar ranking can be found for the *private_time* variable.

As far as the spatial structure and the urban dynamics are concerned, the following considerations can be made:

- urban systems are quite comparable in terms of area (which, however, is on average decreasing from the North to the Islands), while on average Northern systems are much more populated than the others. As for residential density, Southern cities are on average the most compact (followed by Northern ones);
- the most dynamic cities in terms of house building and population growth (1981-2001) are found in Southern Italy and in the Islands;
- cities in Central Italy are on average the most dispersed. They are characterized by the lowest density, the highest rural share, the least compact residential structure. Nevertheless, their pivot municipalities

appear to be the most functionally diversified and concentrate the highest share of the system's population and employment;

- the distribution of both population and employment within the urban systems is most concentrated in the North – as opposed to the Islands. Looking at the pivot itself, however, its population (and employment) share is lowest right in the North, which may suggest that Northern systems tend to have a more polycentric structure.

We now look at the different urban systems taking into account their population size. In particular, Italian cities have been grouped on the basis of four population classes: cities with more than 400,000 inhabitants, that, simplifying, can be seen as metropolitan areas; upper-middle scale cities, with population between 200,000 and 400,000; lower-middle scale cities, with population between 100,000 and 200,000; and, finally, the urban systems with less than 100,000 inhabitants.

The descriptive analysis by population size may be useful, especially to find out whether some patterns of mobility and/or spatial organization of cities are subject, at least to some extent, to some scale effect. The following findings are worth mentioning:

- the public transport share increases with population. As expected, people are more likely to use public means of transport in more populated (and more densely inhabited) cities, where there are scale economies in the provision of public local goods – like public transport infrastructure – and the higher level of congestion makes it less convenient to use private motorized means of transport;
- commuting times are increasing in population, but the smallest systems are more congested than those with population between 100,000 and 200,000 inhabitants. The same pattern is found for density. Coherently, the rural share and the dispersion of the residential structure are decreasing in population, but – as above – these tendencies reach a turning point when the smallest urban systems come into play;
- the intensity of the private motorized transport is decreasing in population;
- the most dynamic cities in terms of house building and population growth (1981-2001) are the smallest systems, while the least dynamic are the biggest;

- in the smallest systems the pivot municipality tend to play a major role and seem to be more functionally diversified;
- concentration of both employment and population is increasing in population. This finding, coupled with the evidence that in the largest cities the pivot itself do not account for the highest population (and employment) share, may mean that bigger cities have a more polycentric structure than smaller ones.

4 Towards a taxonomy?

4.1 Linking mobility patterns to urban structure: a factor analysis

As briefly reviewed in paragraph 2, lots of works in urban studies and urban economics literature suggest that the patterns of mobility within a urban system depend, among other things, upon the form of the system, that is the way it is spatially organized in terms of population, employment, land consumption and so on.

The aim of this paragraph is to carry out an explorative analysis of the Italian urban systems, taking account of their spatial structure and their patterns of commuting-to-work mobility at the same time, in an attempt to synthesize, where possible, all these inter-linked features. In this perspective, a factor analysis is carried out in order to reduce data, hence making Italian urban systems easier to interpret in the light of their inter-dependent structure-mobility features. Data reduction has been applied – following the principal factors method – on six variables pertaining to urban form (*ldensity*, *sprawl*, *rural_share*, *house_age*, *pivot_mix*, *gini_area_pop*), along with the three variables pertaining to mobility patterns (*public_share*, *public_time* and *priv_intensity*). On selecting the variables, two criteria have been followed:

- *relevance* of the variables according to our interpretation scheme;
- *thrift*.

In other words we have tried to include all the variables that are able to capture some aspects of either urban structure or mobility patterns (or both), avoiding to consider a variable that is somewhat a duplication of another and may turn out to be redundant. That is why the employment concentration variable – *gini_area_empl* – has not been included, since it shows a fairly similar behaviour as *gjni_area_pop*, thus it may have prove redundant. Likewise, the variables referred to the pivotal municipality – *pivot_pop_share* and *pivot_empl_share* – have been ruled out, on the basis that the Gini concentration index captures pretty much the same urban characteristics but should be more comprehensive, in that it takes into account the relative importance of each municipality within the system (rather than the relative weight of the pivot only). Having said this, the factor analysis output is presented below:

Tab. 5 Factor analysis output: eigenvalues and proportions of "explained" variability

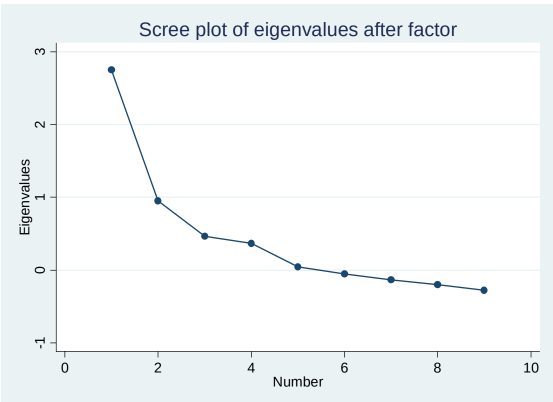
Factor analysis/correlation			Number of obs	111
Method: principal factors			Retained factors	5
Rotation: (unrotated)			Number of params	35

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor 1	2.74953	1.79589	0.7021	0.7021
Factor 2	0.95363	0.49014	0.2435	0.9457
Factor 3	0.46349	0.09446	0.1184	1.0640
Factor 4	0.36903	0.32640	0.0942	1.1583
Factor 5	0.04263	0.09313	0.0109	1.1691
Factor 6	-0.05051	0.08543	-0.0129	1.1562
Factor 7	-0.13593	0.06366	-0.0347	1.1215
Factor 8	-0.19959	0.07673	-0.0510	1.0706
Factor 9	-0.27633	.	-0.0706	1.0000

LR test: independent vs. saturated:
chi2(36) = 336.83 Prob>chi2 = 0.0000

Source: our elaboration on Istat Census data

Fig. 1 Eigenvalues plot after the factor analysis



Source: our elaboration on Istat Census data

The output of the factor analysis induces to take one factor only, since the respective eigenvalue accounts for as much as 70.2% of total variance, which is a considerable share. Besides, this is the only eigenvalue remarkably higher than 1, and looking at the eigenvalue plot it can be noted that the slop of the plot, initially very steep, gets flatter and flatter from the second eigenvalue onward. Nevertheless, the second eigenvalue is nearly 1, and could lead to consider another factor.

In this analysis, however, we have preferred to concentrate on the first factor only, if nothing else because of its interpretability[20]. Looking at the factor loadings, indeed, their signs seem to be consistent with our theoretical interpretation: for instance, *factor 1* is positively saturated by *ldensity* – a measure of compactness – as opposed to *sprawl*, *rural_share* and *house_age* – measures of dispersion – that all enter with a negative sign. Moreover, *public_share* has a positive sign, a hint of the tendency of more compact and concentrated – as well as congested – cities to make a more intense use of public means of transport. Thus this factor seems to synthesize quite well the mobility and spatial structure of the Italian urban systems, which was an expected result, given the high degree of correlation between most variables relating to the two urban dimensions of interest.

Tab. 6 Factor analysis output: (unrotated) factor loadings

Factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Uniqueness
public_share	0.6140	0.4096	0.1104	-0.1387	0.0790	0.4175
priv_intensity	-0.4881	-0.3398	0.0755	-0.3829	0.0129	0.4939
ldensity	0.8467	-0.2863	-0.0458	0.0843	-0.0195	0.1916
public_time	0.7903	-0.0990	0.2757	0.1784	-0.0105	0.2577
sprawl	-0.4202	0.3165	0.0329	0.1335	-0.1488	0.6822
house_age	-0.3615	-0.3927	0.3957	0.1537	0.0064	0.5349
rural_share	-0.6565	0.2256	-0.0089	0.3076	0.1145	0.4104
gini_area_pop	0.1691	0.4698	0.0815	-0.1177	-0.0202	0.7297
pivot_mix	-0.1616	0.2293	0.4507	-0.1197	-0.0059	0.7038

Source: our elaboration on Istat Census data

The next step consists in the computation of the factor scores, which allows us to draft a preliminary ranking of Italian cities. The factor scores are computed as a linear combination – for each urban system – of the relevant variables, where the combination coefficients are the factor loadings:

[20] Having taken one factor only, it is unnecessary to carry out a factor loadings rotation.

$$factor\_score = 0.6140 * public\_share + 0.7903 * public\_time - 0.4202 * sprawl - 0.3615 * house\_age + \\ + 0.8467 * ldensity - 0.6565 * rural\_share - 0.4881 * priv\_intensity - 0.1616 * pivot\_mix + \\ + 0.1691 * gini\_area\_pop \quad (6)$$

Recalling the sign and the size of the factor loadings, it can be understood that at the top of list (Tab. 7) there are more compact, densely inhabited, congested and concentrated cities, where the use of the public means of transport is more intense. By contrast, at the bottom of the list those systems are likely to be found that are more dispersed, more rural, more dynamic in terms of new houses building, with a higher intensity of private motorized commuters and with a less functionally diversified pivot. As expected, most metropolitan areas can be found near the top of the list[21].

Tab. 7 Ranking of all the Italian urban systems by their factor scores

Urban system	factor score	Urban system	factor score	Urban system	factor score
Napoli	11.087	Livorno	7.678	Imola	6.544
Milano	10.313	Modena	7.671	Barletta	6.538
Torre del Greco	10.047	Treviso	7.549	Alessandria	6.530
Castellammare di Stabia	9.865	Bologna	7.538	Fano	6.496
Messina	9.698	Pisa	7.508	Foggia	6.495
Cava de' Tirreni	9.617	Latina	7.453	Caltanissetta	6.473
Bagheria	9.605	Taranto	7.433	Asti	6.435
Venezia	9.581	Cagliari	7.426	Modica	6.422
Roma	9.479	Siracusa	7.416	Potenza	6.416
Aversa	9.468	Pesaro	7.390	Trapani	6.403
Genova	9.460	Avellino	7.384	Sassari	6.348
Trieste	9.342	Agrigento	7.315	Piacenza	6.345
Acireale	9.284	Pescara	7.280	San Severo	6.339
Catania	9.152	Verona	7.258	Parma	6.327
Carrara	9.040	Savona	7.244	Vittoria	6.325
Torino	8.942	Pistoia	7.158	Crotone	6.320
Como	8.636	Brindisi	7.149	Cesena	6.307
Varese	8.635	Vigevano	7.120	Manfredonia	6.288
San Remo	8.561	Lecce	7.041	Faenza	6.263
Busto Arsizio	8.555	Marsala	6.982	Cremona	6.241
Firenze	8.421	Reggio nell'Emilia	6.967	Terni	6.179
Bergamo	8.415	Lucca	6.967	Arezzo	6.174
Palermo	8.406	Forlì	6.908	Gela	6.155
Padova	8.300	Novara	6.864	Teramo	6.102
Brescia	8.284	Bolzano	6.849	Benevento	6.074
Bari	8.207	Pavia	6.836	Ragusa	6.050
Massa	8.117	Trento	6.836	Viterbo	5.998
Rimini	8.093	Catanzaro	6.830	Foligno	5.944
Viareggio	8.060	Rovigo	6.784	Altamura	5.858
Caserta	8.043	Carpi	6.770	Matera	5.833
Reggio di Calabria	8.020	Ravenna	6.763	Ascoli Piceno	5.820
Prato	7.956	Perugia	6.740	Campobasso	5.716
La Spezia	7.881	Ferrara	6.739	Siena	5.589
Ancona	7.847	Lamezia Terme	6.654	L'Aquila	5.565
Bisceglie	7.796	Civitavecchia	6.654	Grosseto	5.497
Vicenza	7.738	Cosenza	6.635	Cuneo	5.260
Salerno	7.711	Udine	6.589	Cerignola	5.107

Source: our elaboration on Istat Census data

21 Clearly, this list do not rank the Italian cities from the most virtuous to the most vicious. It just ranks them according to the different degree with which, in each city, spatial-structure and mobility characteristics tend to manifest themselves.

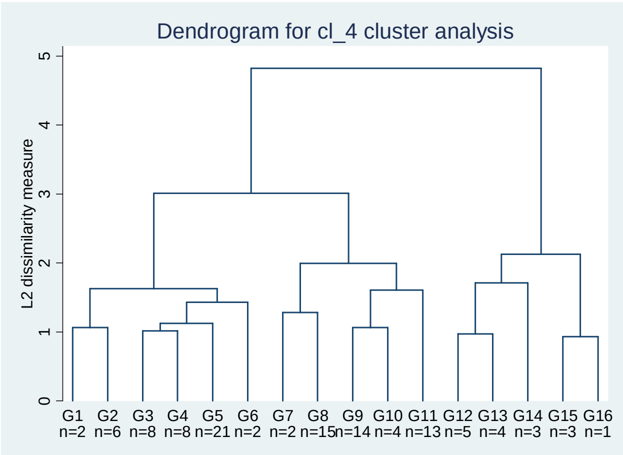
4.2 A cluster analysis

The computation of the factor scores after the factor analysis allows ranking the Italian urban systems by their spatial structure and mobility patterns features, that appear to be strongly linked to each other. In this paragraph an attempt is made to cluster the Italian cities, grouping together those systems that present a similar degree of, say, urban compactness and public means of transport orientation. It is difficult to make *a priori* assumptions on the number of groups and on their size, because clear-cut distinctions between them cannot be easily found. A distinction does exist, however, when it comes to assess the intensity of such inter-linked phenomena as those described above. It turns out to be the case, indeed, that some cities are more compact (and more congested, and more public transport oriented etc.) than others. Ideally, we want to identify prospective clusters of cities that are built on the basis of their different degree of compactness (and of congestion, and of public transport orientation etc.) and hence present different mobility patterns.

The cluster analysis has been carried out on the 111 urban systems of our dataset, using the same nine variables as in the factor analysis and following a hierarchical agglomerative approach. In particular, the complete linkage method has been preferred as grouping procedure. According to this method, indeed, as opposed to the single linkage one, the distance between the *k-th* external unit and the newly formed *(i, j)* group is computed as the highest value between the distances d_{ik} and d_{jk} (MacNaughton-Smith, 1965; Johnson, 1967). This method seems to be appropriate if one is to maximize the degree of homogeneity within the groups, especially when, as in this case, the latter are not easily identifiable *a priori*. The cluster dissimilarity matrix has been built using Euclidean distances, though the result of the clustering procedure would not have changed much using square Euclidean distances instead.

The dendrogram (Fig. 2)suggest that three major groups exist, which is confirmed by the Calinski test, while the Duda-Hart test reaches the highest value when the grouping procedure stops at four (Tab. 8). We may have opted for four clusters according to the latter test, but we preferred to form five groups – that can be anyway easily recognized from the dendrogram – so as to avoid dealing with too large clusters that would have been too difficult to interpret. It is worth pointing out that this is just an explorative analysis, and the choice of one more group may be justified by the fact that the urban systems are somehow laid on a *continuum* that goes from the most dispersed-least congested-most private motorized transport oriented to the most compact-most congested-most public transport oriented. Hence group formation at this stage may depend on the extent to which it is desirable to distinguish among systems along that *continuum*.

Fig. 2 Cluster analysis output: dendrogram



Source: our elaboration on Istat Census data

Tab. 8 Cluster stopping rules: Calinski and Duda-Hart tests

Calinski Test	
Number of clusters	Harabasz pseudo-F
2	93.60
3	126.45
4	94.43
5	91.18
6	79.43
7	82.91
8	84.70
9	80.25
10	77.17
11	74.23
12	72.92
13	70.65
14	70.50
15	68.93

Duda/Hart Test		
Number of clusters	Je(2)/Je(1)	pseudo T-squared
1	0.5380	93.60
2	0.4999	93.04
3	0.5861	9.89
4	0.6387	26.03
5	0.4795	10.86
6	0.6490	24.34
7	0.5923	19.96
8	0.7998	9.26
9	0.6019	9.92
10	0.8075	8.34
11	0.6378	9.09
12	0.4987	6.03
13	0.5700	10.56
14	0.5670	5.35
15	0.1621	10.34

Source: our elaboration on Istat Census data

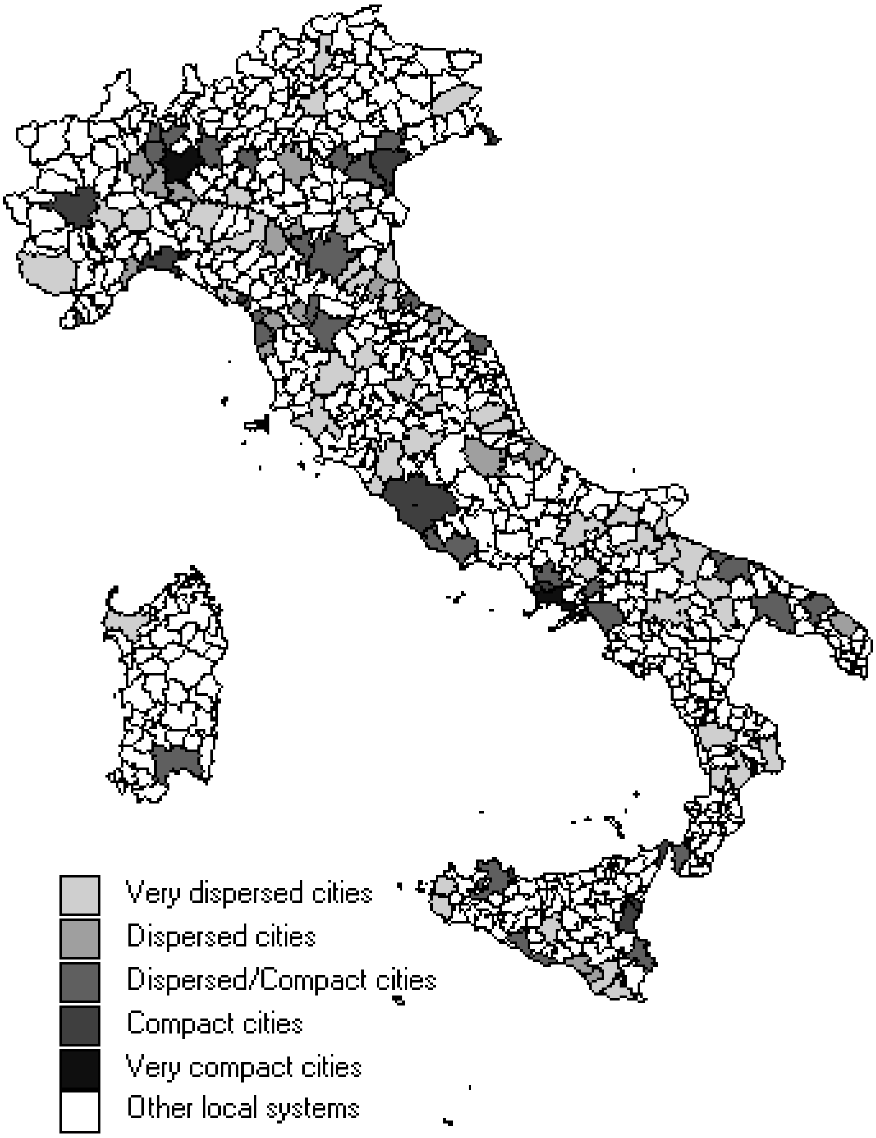
The results of the clustering procedure seem to be consistent with the factor analysis. This means that the groups tend to reflect the ranking obtained with the factor, as also shown by the computation of the average factor score for each cluster. In Table 9 the list of the urban systems in each cluster is presented, while Map 1 shows their territorial distribution. These results, of course, needs further validation. A future step of the research presented in this work, in particular, should be taken in order to assess to which extent the clusters' formation is sensitive to the specific linkage procedure adopted.

Tab. 9 List of Italian cities in each of the five clusters

Cluster 1- Very dispersed	Cluster 2 - Dispersed	Cluster 3 - Dispersed/Compact	Cluster 4 - Compact	Cluster 5 - Very compact
Civitavecchia	Forlì	Taranto	Torino	Castellamare di Stabia
Catanzaro	Pescara	Salerno	Trieste	Torre del Greco
Benevento	Novara	Cagliari	Genova	Milano
Terni	Pavia	Treviso	Acireale	Napoli
Cremona	Verona	Avellino	Carrara	
Fano	Vigevano	Latina	Catania	
Arezzo	Pesaro	Vicenza	Aversa	
Teramo	Livorno	Modena	Cava de' Tirreni	
Faenza	Savona	Ancona	Roma	
Ascoli Piceno	Vittoria	Bologna	Messina	
Cesena	Gela	Rimini	Bagheria	
Imola	Carpi	Prato	Venezia	
Lamezia Terme	Reggio nell'Emilia	Padova		
Foggia	Lecce	Reggio di Calabria		
Ferrara	Lucca	Caserta		
Rovigo	Pistoia	Bergamo		
Asti	La Spezia	Bari		
Parma		Brescia		
Cosenza		Firenze		
Piacenza		Palermo		
Alessandria		Siracusa		
Trento		Brindisi		
Udine		Pisa		
Bolzano		Agrigento		
Grosseto		Bisceglie		
Cuneo		Massa		
Siena		Viareggio		
Campobasso		Busto Arsizio		
L'Aquila		Como		
Crotone		Varese		
Potenza		San Remo		
Foligno				
Sassari				
Barletta				
Perugia				
Cerignola				
Altamura				
Modica				
Ragusa				
Trapani				
Manfredonia				
Ravenna				
Caltanissetta				
Marsala				
Matera				
Viterbo				
San Severo				

Source: our elaboration on Istat Census data

Map 1 Territorial distribution of the urban systems after the cluster analysis



Source: our elaboration on Istat Census data

4.3 Interpreting the clusters

Once the clustering procedure is carried out, it is necessary to look at the clusters more closely, in order to establish which characteristics the cities within each group turn out to share and which label may be attached to that group in an interpretative effort.

Cluster 1 is the most numerous and appear to be composed by the most dispersed cities (Tab. 10). In this group residential density is the lowest, while the rural share and the share of houses built after 1982 are the highest[22], as well as the residential structure is the most scattered. Accordingly, the intensity of private motorised commuting is the highest, whereas the functional diversity of the pivot is the lowest. Cities belonging to this group are characterised by a high degree of urban sprawl and mobility is largely dependent upon the automobile. This may have a twofold reason: first, public transport services are arguably less pervasive and efficient in a dispersed territory. This can also be explained by the fact that 43 cities out of 47 have less than 100,000 inhabitants. A small population size, indeed, may imply the absence of scale economies in the supply of public transport infrastructure. Second, given the peculiar low-density urban structure, in these systems congestion is low and, as a result, commuting times are shorter, which may act as an incentive to use private cars and motorbikes. Other distinctive features of this group are the following: cities are on average the smallest in terms of population size, but the largest in terms of total area. Secondly, 33 cities out of 47 are located in Central and Southern (Islands excluded) Italy, evidence of a noticeable territorial pattern.

Tab. 10 Summary statistics by cluster: cluster 1

cluster 1	Very dispersed cities				
Variable	Obs	Mean	Std. Dev.	Min	Max
public_share	47	0.0357	0.0227	0.0075	0.1009
priv_intensity	47	0.5849	0.0846	0.3521	0.7872
ldensity	47	5.0344	0.3781	4.1149	5.4887
public_time	47	3.6183	0.2841	2.8300	4.3600
sprawl	47	0.1436	0.0983	0.0075	0.4161
house_age	47	0.2219	0.0470	0.1005	0.3058
rural_share	47	0.7179	0.1181	0.5141	1.0470
gini_area_pop	47	0.3247	0.1462	0.0452	0.6042
pivot_mix	47	0.1084	0.0609	0.0069	0.2232
factor score	47	6.2841	0.4306	5.1066	6.9825

Source: our elaboration on Istat Census data

Cities in cluster 2 have similar features – albeit less accentuated – as cities in cluster 1 (Tab. 11). In particular, the urban form of the former is rather dispersed,

[22] The highest share of houses built after 1982 is indeed consistent with the relatively high rate of population growth in the 1981-2001 period.

but less than in the latter. Cities in cluster 2, however, are less congested and population is more evenly distributed within them, which perhaps explain the even lower share of public transport users. Moreover, pivot municipalities concentrate on average quite a small population share, but are relatively diversified in functional terms. These systems are rather small both in terms of area and population and have experienced – on average – a negative population variation in the 1981-2001 period. Finally, 14 out of 17 cities in this group are located in Northern and Central Italy, including one metropolitan area (Verona).

Tab. 11 Summary statistics by cluster: cluster 2

cluster 2	Dispersed cities				
Variable	Obs	Mean	Std. Dev.	Min	Max
public_share	17	0.0338	0.0248	0.0036	0.0921
priv_intensity	17	0.5772	0.1048	0.4761	0.9333
ldensity	17	5.8429	0.2541	5.4304	6.4023
public_time	17	3.5829	0.2718	2.9400	3.8900
sprawl	17	0.0938	0.0563	0.0132	0.1829
house_age	17	0.1873	0.0612	0.0597	0.2744
rural_share	17	0.6102	0.1345	0.2740	0.7864
gini_area_pop	17	0.3057	0.1419	0.0803	0.5309
pivot_mix	17	0.0757	0.0730	0.0004	0.2608
factor score	17	7.0496	0.4235	6.1547	7.8807

Source: our elaboration on Istat Census data

Following our interpretation scheme, the urban systems grouped in clusters 4 and 5 (Tables 12 and 13 respectively) are the "farthest" from those in cluster 1 (and to a lesser extent from those in cluster 2), in that they tend to have, on average, the most compact form and the most public-oriented pattern of mobility. What distinguishes the two clusters is the intensity with which such tendencies (i.e., compact spatial structure and public-oriented commuting) can be observed. The four urban systems in cluster 5, indeed, show the highest residential density as well as the least dispersed residential structure. As regarding mobility patterns, in such systems congestion is highest and the incidence of private motorized commuters is the lowest, whereas the use of public means of transport is the most intense. These features also characterize the cities in cluster 4, though the values of the relevant variables are less accentuate (except for *rural_share*, which in this case is the lowest).

If one is to investigate the nature of these systems more in detail, it turns out that in cluster 5 the cities seem to act as outliers, especially as far as residential density is concerned – being almost 16 times higher than in cluster 1 cities and, still, 2.8 times higher than in cluster 4 cities, which are the second most compact. In cluster 5, indeed, we find two large metropolitan areas – Milan and Naples – and two other urban systems that are contiguous to Naples and arguably form with the latter a unique metropolitan area. These four cities are on average the most populated but the least large in terms of total area. What is more, their pivots on average account for the smallest population shares, while population concentration is the lowest (though the Gini index does not show great variability among the clusters). This suggest that the urban landscape in this areas is extremely dense and uniform.

Tab. 12 Summary statistics by cluster: cluster 4

cluster 4	Compact cities				
Variable	Obs	Mean	Std. Dev.	Min	Max
public_share	12	0.1029	0.0885	0.0140	0.2666
priv_intensity	12	0.5113	0.0809	0.3828	0.6242
ldensity	12	6.8023	0.2631	6.2105	7.1470
public_time	12	5.1825	0.4505	4.5900	6.0300
sprawl	12	0.0391	0.0441	0.0064	0.1371
house_age	12	0.1921	0.0945	0.0460	0.3773
rural_share	12	0.3657	0.1397	0.1384	0.6094
gini_area_pop	12	0.3399	0.1869	0.0509	0.5881
pivot_mix	12	0.0712	0.0430	0.0062	0.1535
factor score	12	9.3889	0.2415	8.9417	9.6982

Source: our elaboration on Istat Census data

Tab. 13 Summary statistics by cluster: cluster 5

cluster 5	Very compact cities				
Variable	Obs	Mean	Std. Dev.	Min	Max
public_share	4	0.1212	0.0887	0.0436	0.2217
priv_intensity	4	0.4282	0.0153	0.4144	0.4465
ldensity	4	7.8197	0.3153	7.5771	8.2832
public_time	4	5.2550	0.2619	5.0600	5.6200
sprawl	4	0.0111	0.0034	0.0063	0.0144
house_age	4	0.1886	0.0195	0.1600	0.2034
rural_share	4	0.4189	0.0793	0.3221	0.5069
gini_area_pop	4	0.3046	0.0911	0.1978	0.4057
pivot_mix	4	0.0945	0.0585	0.0198	0.1625
factor score	4	10.3278	0.5387	9.8647	11.0874

Source: our elaboration on Istat Census data

Cluster 4 cities, by contrary, are characterized on average by a large scale (both in population and in total area terms), their pivots are the most functionally diversified and account for the largest population shares – which is also consistent with the highest value that such cities show for the Gini index. In this group we find five metropolitan areas – Turin, Genoa, Catania, Rome and Venice – and three other largely populated systems – Trieste, Messina and Aversa (with the latter contiguous to Naples).

Finally, cluster 3 (Tab. 14) is made up of all the systems *in between*, in that they do not stand out either for their compactness (and public-oriented mobility) or for their dispersion (and private motorized-oriented mobility). These cities are quite uniformly spread over the national territory and are on average highly populated (22 out of 31 have more than 200,000 inhabitants). Furthermore, they have been the most dynamic in terms of population variation in the 1981-2001 period and are characterized by pivots whose population share over the whole system is fairly low on average, although population distribution over the system is fairly concentrated. These findings, taken together, may actually suggest that these systems are organized in a polycentric way, though it has not been possible, at this stage, to build an indicator of polycentrism able to capture the degree of population or employment clustering within each system (like the Moran indicator in Tsai, 2005).

Tab. 14 Summary statistics by cluster: cluster 3

cluster 3	Dispersed/Compact cities				
Variable	Obs	Mean	Std. Dev.	Min	Max
public_share	31	0.0493	0.0288	0.0115	0.1152
priv_intensity	31	0.5545	0.0526	0.4835	0.6628
ldensity	31	6.2111	0.3888	5.4681	6.9893
public_time	31	4.2310	0.2065	3.8800	4.7100
sprawl	31	0.0814	0.0695	0.0111	0.2561
house_age	31	0.2194	0.0618	0.0754	0.4025
rural_share	31	0.5556	0.1570	0.2073	0.7677
gini_area_pop	31	0.3342	0.1442	0.0226	0.6956
pivot_mix	31	0.1027	0.0713	0.0008	0.2432
factor score	31	7.9240	0.4420	7.1492	8.6364

Source: our elaboration on Istat Census data

The fifth most populated urban system – Palermo – and other eight middle-scale metropolitan areas – Cagliari, Taranto, Bari, Bologna, Firenze, Padova, Bergamo and Busto Arsizio – belong to this cluster. Although a clear-cut territorial pattern is difficult to find, it is worth pointing out that in this cluster there are two *greater* metropolitan areas: the Lombardia and the Veneto areas. The former is formed by Bergamo, Busto Arsizio, Como and Varese – that are all contiguous to Milan – plus Brescia – that is also in Lombardia but does not border with Milan. The latter is made up of Padua, Vicenza and Treviso – which are all contiguous and strongly linked to Venice. These greater metropolitan areas are integrated at a larger scale and their borders are not easily identifiable. In addition, their main core – Milan and Venice respectively – belong to groups of more compact cities.

5 Concluding remarks

This work is intended to investigate the Italian urban systems in terms of their spatial organization and mobility patterns, in an attempt to build a taxonomy. Two stylized facts seem to emerge from the descriptive analysis: first of all, cities' spatial-mobility structure is significantly heterogeneous across Italy. Secondly, the patterns of commuting-to-work mobility within cities appear to be strongly linked to the urban form.

These findings allow us to distinguish between the Italian cities on the basis of their spatial organization and mobility patterns. Indeed, different *degrees* of, say, compactness, congestion and public transport use can be observed among the different urban systems, as shown by the factor analysis. In this perspective, a cluster analysis has been carried out in order to group together cities with homogeneous characteristics. Five groups have been identified, ranging from the most dispersed to the most compact cities. Within each group, a consistent combination of spatial structure and mobility features can be observed.

This preliminary exploration should be refined, in order to reach an ever more accurate identification of the groups of cities. Moreover, once the latter are classified in the light of their spatial organization and pattern of mobility, further analysis should be carried out, so as to gain a deeper knowledge as to how different cities (or group of cities) perform in terms of static and (above all) dynamic efficiency, especially from a spatial point of view. It should be noted, indeed, that different pattern of spatial organization and development entail different types and levels of social costs. Hence, a comparison in this perspective may prove extremely interesting, all the more so as the challenge of (long-term) environmental sustainability is by now ineludible.

References

Alonso W. (1964), *Location and land use*, Harvard University Press, Cambridge;

Altshuler A. (1997), "Review of the cost of Sprawl", *Journal of the American Planning Association*, n. 43;

Anas A., Arnott R., Small K. A. (1998), "Urban spatial structure", *Journal of Economic Literature*, Vol. 36, n. 3;

Arnott R. (1979), "Optimal city size in a spatial economy", *Journal of Urban Economics*, 61, pp. 65-89;

Bertuglia S. C., Stanghellini A., Staricco L. (2002), "Gestire la città e il territorio nell'epoca della diffusione urbana", *Economia Italiana*;

Brueckner J. K. (2001), "Urban sprawl: lessons from Urban Economics", *Brookings-Wharton Papers on Urban Affairs*, pp. 65-97;

Brueckner J. K., Fansler D. A. (1983), "The economics of urban sprawl: theory and evidence on the spatial size of cities", *The Review of Economics and Statistics*, Vol. 65, pp. 479-482;

Calafati A. G. (2003), "Economia della città dispersa", *Economia Italiana*, n.1;

Calafati A. G. (2005), "From 'territory' to 'city': the conceptualisation of space in Italy since 1950", UPM – Dept. of Economics, *Working Papers Series*, n. 241;

Calafati A. G. (2007), "La città come 'sistema progressivo': evoluzione strutturale e sviluppo economico", UPM-Dept. of Economics, *Working Papers Series*, n. 290;

Camagni R. (2002), "Città e qualità della vita: problemi e prospettive per le città italiane", *Economia Italiana*.

Camagni R. (1996) (a cura di), *Economia e pianificazione della città sostenibile*, Il Mulino, Bologna.

Camagni R., Gibelli M. C., Rigamonti P. (2002), *I costi collettivi della città dispersa*, Alinea, Firenze;

Camagni R., Nijkamp P., Travisi C. M. (2006), "Analysis of Environmental Costs of Mobility due to Urban Sprawl - A Modelling Study on Italian Cities," Tinbergen Institute Discussion Papers 06-042/3, Tinbergen Institute.

Camagni R., Travisi C., (2006) "L'insostenibilità dello sprawl urbano: un'analisi dell'impatto della mobilità in Italia", *Scienze Regionali*, Vol. 5, n. 3;

Champion A. G. (2001), "A Changing Demographic Regime and Evolving Polycentric Urban Regions: Consequences for the Size, Composition and Distribution of City Populations", *Urban Studies*, Vol. 38, No. 4, pp. 657-677.

Dubois-Taine G., Chalas Y. (1997) (eds.), *La ville émergente*, Editions de l'Aube, Paris;

Ewing R. (1997), "Is Los Angeles-style sprawl desirable?", *Journal of the American Planning Association*, 63 (1), pp. 107-126;

Ewing R., Pendall R., Chen D. (2002), *Measuring Sprawl and its Impact*, Smart Growth America, Washington D.C.;

Galster G., Hanson R., Ratcliffe R. *et al.* (2001), "Wrestling sprawl to the ground: defining and measuring an elusive concept", *Housing policy debate*, 12 (4), pp. 681-717;

Gordon P., Richardson H. W. (1997), "Are compact cities a desirable planning goal?", *Journal of the American Planning Association*, 63 (1), pp. 95-106;

Hoogstra G., Van Dijk J., Florax R. (2005), “Do jobs follow people or people follow jobs? A meta-analysis of Carlino-Mills studies”, ERSA Conference papers, European Regional Studies Association, revised.

Jacobs J. (1961), *The Death and Life of Great American Cities*, Random House and Vintage Books, New York;

Lattarulo P. (2003), *I costi ambientali e sociali della mobilità*, Franco Angeli, Milano;

Le Roy S., Sonstelie J. (1983), “Paradise lost and regained: transportation innovations, income and residential locations”, *Journal of Urban Economics*, 13 (1), pp. 67-89;

Lynch K., Rodwin L. (1958), “A theory of urban form”, *JAIP*, Vol. 24, n. 4;

Mieszkowski P., Mills E. S. (1993), “The causes of metropolitan suburbanization”, *Journal of Economic Perspective*, Vol. 7, n. 3, pp. 135-147;

Mills E. S. (1967), “An aggregative model of resource allocation in a metropolitan area”, *American Economic Review*, 57, pp. 197-210;

Muth R. (1969), *Cities and houses*, Chicago University Press, Chicago;

Pouyanne G. (2006), “Land use diversity and daily mobility: the case of Bordeaux”, *Scienze Regionali*, Vol. 5, n. 3.

Salatino M. (2006), “La correlazione tra forma urbana e mobilità nei paesi dell’EU: un’analisi statistica”, *Scienze Regionali*, Vol. 5, n. 3.

Salatino M. (2004), “Dispersione urbana e costi collettivi del trasporto privato nelle regioni italiane”, presented at the XXV Italian Conference of Regional Science, 6-8 October 2004, Novara;

Sassen S. (1994), *Cities in a world economy*, Thousands Oaks, Pine Forge Press;

Tsai Y. H. (2005), “Quantifying urban form: compactness versus ‘sprawl’”, *Urban Studies*, Vol. 42, n. 1, 141-161, January;

Weathon W. C. (1998), “Land use and density in cities with congestion”, *Journal of Urban Economics*, 43, pp. 258-272;

Weber M. (1950), *La città*, Bompiani, Milano.

Appendix I

A Box-Cox regression has been carried out to estimate the most suitable transformation function of the area. The model is the following:

$$(average\_pu\_time)^{(\lambda)} = \alpha + \beta * (area)^{(\lambda)}$$
(i)

where

$$(area)^{(\lambda)} = \frac{(area)^{\lambda} - 1}{\lambda}$$
(ii)

The parameters *α, β,* and *λ* are estimated simultaneously. We want to test the null hypothesis

$H_0 : \lambda \to 0$ which would imply that $(area)^{(\lambda)} = \ln(area)$.

The null hypothesis is not rejected as shown in the following table:

Test H_0	Restricted log likelihood	LR statistic chi^2	P-Value Prob > chi^2
$\lambda = 0$	-296.16856	2.54	0.111

Appendix II

Tab. A1 Summary statistics by macro-area: Northern Italy

macro-area 1	North				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	28	824.1	499.7	117.0	2,475.0
population	28	445,505	592,312	55,542	2,975,754
density	28	541.1	440.3	62.5	2,210.8
sprawl	28	0.0975	0.0793	0.0063	0.2777
rural_share	28	0.5664	0.2416	0.1384	1.0470
pivot_pop_share	28	0.4653	0.1934	0.1343	0.9112
pivot_empl_share	28	0.5522	0.1959	0.1404	0.9445
gini_area_pop	28	0.3910	0.1083	0.1868	0.6042
gini_area_empl	28	0.4705	0.1076	0.2773	0.7063
pivot_mix	28	0.0869	0.0486	0.0061	0.1921
house_age	28	0.1758	0.0664	0.0460	0.2948
pop_var_81_01	28	-0.0176	0.0414	-0.0980	0.0538
public_share	28	0.0753	0.0663	0.0115	0.2666
public_time	28	4.1	0.6	3.2	6.0
private_time	28	2.2	0.4	1.6	3.0
priv_intensity	28	0.5064	0.0543	0.3521	0.5863

Source: our elaboration on Istat Census data

Tab.A2 Summary statistics by macro-area: Central Italy

macro-area 2	Centre				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	39	821.7	661.3	85.0	3,657.0
population	39	267,479	529,919	73,382	3,374,511
density	39	331.5	220.3	61.2	922.8
sprawl	39	0.1401	0.0719	0.0210	0.3082
rural_share	39	0.6657	0.1282	0.2722	0.9009
pivot_pop_share	39	0.6319	0.1418	0.3172	0.8862
pivot_empl_share	39	0.7058	0.1293	0.4163	0.9320
gini_area_pop	39	0.3267	0.1485	0.0226	0.5592
gini_area_empl	39	0.3936	0.1630	0.0303	0.6267
pivot_mix	39	0.0766	0.0538	0.0004	0.2116
house_age	39	0.1972	0.0448	0.0957	0.3010
pop_var_81_01	39	0.0079	0.0362	-0.0604	0.1461
public_share	39	0.0405	0.0379	0.0044	0.1992
public_time	39	3.8	0.4	3.1	5.3
private_time	39	2.1	0.3	1.5	3.3
priv_intensity	39	0.5583	0.0527	0.4835	0.7126

Source: our elaboration on Istat Census data

Tab. A3 Summary statistics by macro-area: Southern Italy

macro-area 3	South				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	28	723.9	412.4	50.0	1,500.0
population	28	275,260	406,193	61,084	2,235,602
density	28	603.9	857.1	88.6	3,956.8
sprawl	28	0.0884	0.1093	0.0064	0.4161
rural_share	28	0.6133	0.1509	0.3221	0.9064
pivot_pop_share	28	0.5179	0.2071	0.1897	0.9447
pivot_empl_share	28	0.6485	0.1946	0.2880	0.9556
gini_area_pop	28	0.2931	0.1363	0.0452	0.5064
gini_area_empl	28	0.4089	0.1810	0.0186	0.6935
pivot_mix	28	0.1319	0.0743	0.0110	0.2608
house_age	28	0.2440	0.0495	0.1631	0.4025
pop_var_81_01	28	0.0391	0.0384	-0.0460	0.1079
public_share	28	0.0469	0.0309	0.0140	0.1698
public_time	28	4.0	0.7	2.8	5.6
private_time	28	2.1	0.4	1.6	3.2
priv_intensity	28	0.5603	0.0888	0.3863	0.7872

Source: our elaboration on Istat Census data

Tab. A4 Summary statistics by macro-area: Sardegna and Sicilia

macro-area 4	Islands				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	16	652.7	417.5	106.0	1,687.0
population	16	232,059	215,774	84,081	856,152
density	16	425.2	316.8	130.1	1,098.8
sprawl	16	0.0444	0.0470	0.0070	0.1984
rural_share	16	0.5255	0.1419	0.2804	0.7747
pivot_pop_share	16	0.5865	0.1604	0.3140	0.9517
pivot_empl_share	16	0.6901	0.1366	0.5415	0.9742
gini_area_pop	16	0.2638	0.1799	0.0762	0.6956
gini_area_empl	16	0.3107	0.1942	0.0853	0.7650
pivot_mix	16	0.1051	0.0752	0.0008	0.2432
house_age	16	0.2518	0.0504	0.1822	0.3773
pop_var_81_01	16	0.0392	0.0611	-0.1025	0.1614
public_share	16	0.0313	0.0256	0.0036	0.0774
public_time	16	4.1	0.9	2.9	5.7
private_time	16	2.2	0.5	1.7	3.6
priv_intensity	16	0.6685	0.0921	0.5225	0.9333

Source: our elaboration on Istat Census data

Tab. A5 Summary statistics by population classes: cities with 400,000 inhabitants or more

pop_class 1	> 400,000				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	17	1,315.8	743.9	521.0	3,657.0
population	17	1,077,906	917,574	453,107	3,374,511
density	17	940.3	895.8	273.4	3,956.8
sprawl	17	0.0504	0.0532	0.0063	0.1959
rural_share	17	0.4883	0.1630	0.1384	0.7176
pivot_pop_share	17	0.4867	0.1908	0.1343	0.8434
pivot_empl_share	17	0.5902	0.2013	0.1404	0.9005
gini_area_pop	17	0.4269	0.1285	0.1868	0.6956
gini_area_empl	17	0.5055	0.1306	0.2773	0.7650
pivot_mix	17	0.1034	0.0619	0.0061	0.2334
house_age	17	0.1948	0.0662	0.0460	0.3004
pop_var_81_01	17	-0.0036	0.0418	-0.0980	0.0663
public_share	17	0.1134	0.0735	0.0115	0.2666
public_time	17	4.6	0.6	3.7	6.0
private_time	17	2.6	0.4	2.0	3.3
priv_intensity	17	0.5308	0.0797	0.3828	0.6628

Source: our elaboration on Istat Census data

Tab. A6 Summary statistics by population classes: cities with population between 200,000 and 400,000 inhabitants

pop_class 2	200,000 - 400,000				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	26	684.2	392.5	131.0	1,548.0
population	26	284,699	63,725	190,515	408,746
density	26	590.9	442.5	179.0	2,247.4
sprawl	26	0.0869	0.0732	0.0064	0.2561
rural_share	26	0.5291	0.1642	0.2073	0.7626
pivot_pop_share	26	0.4387	0.2040	0.1897	0.9517
pivot_empl_share	26	0.5216	0.1944	0.2666	0.9742
gini_area_pop	26	0.3386	0.1073	0.0762	0.5023
gini_area_empl	26	0.4160	0.1213	0.0987	0.6935
pivot_mix	26	0.0844	0.0615	0.0008	0.2608
house_age	26	0.2196	0.0504	0.0823	0.3010
pop_var_81_01	26	0.0214	0.0522	-0.1025	0.1461
public_share	26	0.0499	0.0356	0.0138	0.1856
public_time	26	4.1	0.5	3.3	5.4
private_time	26	2.2	0.4	1.6	3.6
priv_intensity	26	0.5523	0.0601	0.4351	0.6597

Source: our elaboration on Istat Census data

Tab. A7 Summary statistics by population classes: cities with population between 100,000 and 200,000 inhabitants

pop_class 3	100,000 - 200,000				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	47	739.2	425.6	72.0	2,475.0
population	47	146,551	30,410	103,330	204,895
density	47	286.0	285.6	62.5	1,953.0
sprawl	47	0.1331	0.0922	0.0111	0.4161
rural_share	47	0.6702	0.1358	0.3295	1.0470
pivot_pop_share	47	0.5674	0.1365	0.3140	0.8842
pivot_empl_share	47	0.6767	0.1105	0.3961	0.9002
gini_area_pop	47	0.3130	0.1434	0.0489	0.6042
gini_area_empl	47	0.4034	0.1728	0.0303	0.7063
pivot_mix	47	0.1119	0.0724	0.0004	0.2432
house_age	47	0.2018	0.0580	0.0597	0.4025
pop_var_81_01	47	0.0032	0.0346	-0.0766	0.0611
public_share	47	0.0382	0.0233	0.0044	0.1009
public_time	47	3.7	0.4	2.9	5.1
private_time	47	2.0	0.2	1.6	2.8
priv_intensity	47	0.5659	0.0783	0.3521	0.7807

Source: our elaboration on Istat Census data

Tab. A8 Summary statistics by population classes: cities with 100,000 inhabitants or less

pop_class 4	< 100,000				
Variable	Obs	Mean	Std. Dev.	Min	Max
area	21	520.6	411.5	50.0	1,586.0
population	21	81,505	13,931	55,542	108,677
density	21	333.4	334.0	61.2	1,270.3
sprawl	21	0.0957	0.0923	0.0122	0.3082
rural_share	21	0.6592	0.2019	0.2291	0.9064
pivot_pop_share	21	0.7243	0.1245	0.4618	0.9447
pivot_empl_share	21	0.7995	0.1100	0.5667	0.9556
gini_area_pop	21	0.2546	0.1675	0.0226	0.5592
gini_area_empl	21	0.3130	0.1837	0.0186	0.6230
pivot_mix	21	0.0757	0.0447	0.0050	0.1609
house_age	21	0.2364	0.0660	0.0754	0.3773
pop_var_81_01	21	0.0426	0.0586	-0.0747	0.1614
public_share	21	0.0228	0.0123	0.0036	0.0458
public_time	21	4.0	0.8	2.8	5.7
private_time	21	2.0	0.4	1.5	2.9
priv_intensity	21	0.5886	0.1195	0.3863	0.9333

Source: our elaboration on Istat Census data