

Spatial structure and the environmental costs of commuting in the Italian cities^{*}

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Abstract

The aim of this paper is to investigate the relationship between the impact of mobility and the different characteristics of urban organization, which have been studied in terms of urban spatial structure (e.g., compactness, monocentricity, spatial concentration of employment, functional diversity), urban dynamics and relative competitiveness of public means of transport. Following previous contributions in this field of research, an index has been calculated that captures the environmental impact of mobility as caught by commuting-to-work flows. The analysis is carried out through a simple econometric model, using cross-section data referring to 111 Italian functional urban areas that are identified with those Italian Local Labour Systems (SLL) that contain a municipality with at least 50,000 inhabitants in 2001.

Key words: urban spatial structure, impact of mobility, environmental costs

JEL – classification codes: Q56, R14, R41

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1. Introduction

This work places itself in that prolific field of literature that has been investigating the economic effects of spatial processes, especially at the urban and metropolitan level. Depending on the way a city is spatially organized – as well as on the pace and timing of its dynamics –, alternative patterns of development may be followed, with different outcomes in terms of environmental, social and economic externalities.

The aim of this paper is to describe the major Italian cities in terms of their spatial structure, which in turn both affects and is influenced by the patterns of mobility within (and among) the cities. In this perspective, it has been argued that a “dispersed city” tends to be less sustainable than a high-density and compact agglomeration, since the former encourages a more intense use of private means of transport. Nevertheless, the advocates of the *ville emergent* (Dubois-Taine and Chalas, 1997) maintain that only free-market localisation and construction decisions may lead to an optimal urban form, all the more so as a “compact city” is likely to be beset with congestion problems¹.

The spatial structure of a territory and especially of urban and metropolitan areas may result in different types and levels of environmental, social and economic externalities. Indeed, micro-decisions about land use, public infrastructure construction and housing investments, generate macro-effects that are unlikely to be taken into account in the private agents’ decision-making process, although they may bring about costs that affect the well-being of the local community and even the society at large.

These market failures are determined by an underestimation of the social costs generated by the private choices concerning transportation and housing, as well as the public choices regarding urban planning, zoning etc. The irreversible allocation of an inherently scarce resource like land to a low-density residential use in the outskirts of a city, for instance, entails relevant long-run consequences on the environment that are usually neglected².

Likewise, a dispersed and discontinued settlement that has not developed in line with the pre-existent public infrastructure, may imply high economic and environmental costs in terms, respectively, of higher access costs to public transportation (and other utilities) and of a more intense (and less sustainable) use of highly polluting means of transport. Not only these costs tend to be ignored or underestimated, but urban planning deregulation may actually lead to the paradox that house construction and firm localisation in a newly developing dispersed area are actually less costly – benefiting from lower urbanisation burdens and looser legal constraints.

It is extremely difficult to isolate and measure accurately all the externalities that society incur depending on the actual pattern of mobility – and the related spatial structure – within the cities. In this work, indeed, the focus is narrowed to the *environmental* costs of mobility and on their prospective determinants. For this purpose, an impact indicator has been built that may approximate the

¹ The debate on urban dispersion and on its economic implications – as opposed to the compact city – has become increasingly lively in the scientific community in the last decades. Regarding the Italian experience, a few relevant case studies have also been analysed concerning some large- and middle-scale metropolitan areas (see Camagni *et al.*, 2002a; Camagni *et al.*, 2006; Musolino and Guerzoni, 2003).

² The full opportunity cost of such a decision is hardly taken into account. Land, for instance, could be devoted to alternative (i.e., more ecological) uses.

environmental costs of mobility, with particular regard to the commuting-to-work flows that take place *within* the major Italian cities. The latter have been interpreted as clusters of contiguous and functionally integrated municipalities³ with a pivotal municipality whose population was at least 50,000 in 2001.

The impact indicator has been computed by weighing the actual commuting flows within the cities on the basis of the transport mode (CO₂ emissions) used and the distance travelled by the commuters. This could be a sound proxy for the environmental costs of mobility, because a higher impact is by construction associated with a more intense use of motorised private means of transport as opposed to public transportation. More precisely, each combination of transport mode and distance is associated with a different level of negative environmental externality in terms of CO₂ emissions.

The ultimate aim of the paper is to test empirically the hypothesis that the environmental costs of mobility are determined, among other things, by the spatial organization of the urban system. One of the argument called into question, in particular, is that a dispersed and low-density city tends to be more dependent upon automobile use and turns out to be less sustainable.

The structure of the paper is the following: in section 2 a definition of urban dispersion is proposed, and both its determinants and implications are briefly reviewed. The relationship between urban spatial structure and patterns of mobility is then examined, from a theoretical point of view, in section 3. Section 4 develops a descriptive analysis of the mobility patterns within the Italian cities, while an attempt to build a mobility impact indicator is made in section 5. Finally, the relationship discussed in section 3 is investigated at the empirical level through a simple econometric model, whose main results are then commented and questioned (section 6).

2. The economics of urban dispersion

2.1 Urban dispersion: definition and determinants

The archetypical European (and Italian) city presents the well-known characteristics of the *compact city*. It is densely inhabited, with a rather strong urban identity and a high “relational density” based on proximity (Camagni *et al.*, 2002a). Since the Eighties, however, a new pattern of urban development has arisen in Europe which has led to the formation of the so-called *dispersed city*.

Albeit later if compared to the US experience and to other European countries, the Italian territory has undergone a progressive process of restructuring that has resulted in new forms of spatial organization. Following a period – that approximately goes from the Fifties to the Seventies of the XX century – of intense spatial concentration of both population and employment, since the Eighties the major Italian cities have experienced a process of sub-urbanisation and decentralisation that has gradually led to the formation of many dispersed

³ Namely the *Labour Local Systems* identified by the Italian Statistical Office (Sforzi, 1997).

urban areas⁴. From the Nineties, European policy-makers started to cope with the various problems and costs associated with the process of urban dispersion and began to call into question the massive deregulation in urban planning that was set in motion in the previous years, following the US experience⁵.

Following Muñiz *et al.* (2006), urban dispersion represents a model of spatial organization characterised by low residential density, low shares of population and employment in the “Central Business District” (CBD), low proximity and low functional diversification⁶. Physical discontinuity is another distinguishing feature, in that newly built urban settlements are not necessarily contiguous to the older city.

Regarding the determinants of urban dispersion, it is quite difficult to outline an exhaustive list, but they might be divided in two groups. On the one hand, some broad factors related to global phenomena come into play. Firstly, the evolution of the individual preferences towards a greater valorisation of low-density areas, which allow a closer contact with nature, a quieter environment and less congestion. In addition, isolated housing allows a higher degree of social segregation based on income (and cultural) differences (Camagni *et al.*, 2002a).

Technological progress in the ICT industry is another relevant factor that has significantly affected localisation decisions. For instance, the possibility of home-working and decentralised decision-making and control have reduced the importance of proximity between home and work-place.

Thirdly, technological progress in the transport sector, as well as public programmes of road infrastructure construction, have decreased transportation costs, widening the radius of the *circadian cycles* given a certain travel time.

The second group of determinants are more specific to urban spatial and economic processes. In the real estate industry, to begin with, the rate of new houses construction has accelerated in the last few years in comparison with the previous decades. This has been in turn determined by a large array of factors, among which it is worth mentioning decreasing interest rates, the rising number of one-person families and of “second houses” (Trilla, 2001), “the euro effect” (Naredo *et al.*, 2003) and the typically European risk aversion, as opposed to the North American attitude.

From another point of view, newly developing settlements appear to be more land-consuming than those built during the past decades. This can be explained by the growing faith in the social outcome of free market interactions and the consequent loosening of the building constraints. A further role may be played by the progressive dismantling of the Common Agricultural Policy (CAP), which had allowed a clear separation between rural and urban land uses and prevented a rapid erosion of rural rents and farmers’ real incomes. Finally, the lack of effective public-decision making at the appropriate territorial scale has often resulted in the building of isolated agglomerations of houses, thus leading to the formation of discontinuous and highly land-consuming settlements.

⁴ This model of urban development arose earlier and with higher intensity in North America, where much literature has been produced with respect to both the causes and effects of *urban sprawl* (Mieszkowski and Mills, 1993; Brueckner and Fansler, 1983; Brueckner, 2001).

⁵ The causes and the effects of this peculiar model of urban expansion have been investigated in Europe as well (see for instance Camagni *et al.*, 2002a; Muñiz *et al.*, 2006).

⁶ Urban dispersion involves a process of spatial development that does not build on the functional diversity of the traditional European cities. On the contrary, there is a tendency for different (residential, industrial, tertiary) activities – and often for different social as well as income groups – to be spatially segregated.

Both economic and institutional factors, finally, may affect the localisation of residential and productive activities. For instance, residential functions tend to be crowded out in the CBD by high value-added tertiary activities, which are able to pay higher rents. In addition, the revitalisation of the existing real estate in the historical city centres may be much costlier than the building of new settlements in the suburban areas. An unordered urban development may also be the undesirable outcome of an excessive degree of administrative fragmentation and of fiscal competition among the local municipalities to attract investments.

2.2 The social costs of urban dispersion

In the dispersed versus compact city debate, the advocates of public intervention argue that the free interaction among individual preferences are unlikely to lead to an efficient outcome⁷ because of several market failures. Urban dispersion, indeed, is often associated with a variety of social costs (Altshuler, 1997; Calafati, 2003; Muñiz *et al.*, 2006;).

Following Brueckner (2001), there does not exist a market for open space and, as a result, it is difficult to ascertain how much the taxpayers are willing to pay for public parks, less congestion, or common spaces created for recreational purposes. Secondly, individuals who travel by car do not incorporate their marginal contribution to congestion and pollution in their transport mode decisions. House-builders, in addition, do not take into account the public costs that arise when it comes to providing the new settlements with infrastructure and other utilities. Finally, people tend to take advantage of agglomeration economies without contributing to their generation⁸.

These market failures ultimately stem from economic as well as social and environmental costs that society incurs, but that individual agents do not fully (or even at all) take into account when they make their decisions regarding transport mode choice, localisation and land use. Hence, the free functioning of the market and the spontaneous interaction among the individual preferences do not necessarily lead to an efficient outcome.

Regarding sheer economic costs, a recent study applied to a Spanish case has estimated that private costs – costs of edification, projecting and licensing, other urbanization burdens, heating, water and power consumption, cleanliness etc. – and public costs – connection to the water and sewage system and to other utilities – are much higher for an isolated house than a flat in a block⁹.

Urban dispersion also entails relevant non-economic costs¹⁰. First of all, when a city is dispersed, it is on average more segregated and less accessible. There is a tendency towards a clear separation between different social groups, depending on

⁷ See, among the others, Banister (1997), Brueckner (2001), Camagni *et al.* (2002b). For a discussion on the costs of dispersion in terms of quality of life, see Camagni (2002).

⁸ As a matter of fact, they prefer to locate as close as possible to the agglomeration area in order to benefit easily from agglomeration advantages, without bearing the costs of congestion and of higher land prices (i.e., they try to act as free-riders).

⁹ They are estimated to be, respectively, two and seven times higher (Henry, 2004).

¹⁰ See, for example, Massey and Denton (1988, 1993); Cutler *et al.* (1997); Deurloo and Musterd (1998), Lattarulo (2003).

income levels or racial identity. Secondly, urban dispersion causes a lower access to mobility, especially for children, the elderly and disabled people. Thirdly, higher residential density may enhance a greater sense of safety (Jacobs, 1961; Elkin *et al.*, 1991), although a positive relationship between high density and crime in cities has been found as well (Newman, 1972; Coleman, 1985; Burton, 2000). In a discontinued and dispersed city, moreover, urban identity tends to weaken, though it may turn into a “sense of community” (Delgado, 1999). This effect is often associated with lower acceptance of novelty and diversity and thus – following Florida’s theory (2002) – with a lower capacity of innovation.

Moving on to the environmental effects of urban dispersion, two groups of effects can be identified. One set refers to direct environmental costs of house building in a discontinuous or scattered way, as opposed to a more compact pattern of development. Isolated housing implies more waterproof land and water consumption, a larger loss of rich soil and a higher degree of land fragmentation, which in turn entail less diversity of land uses (Muñiz *et al.*, 2006). A second group of environmental effects stem from the pattern of mobility associated with urban dispersion¹¹. The most relevant effects, in this perspective, are noise and air pollution, occupation of land potentially available for more ecological uses and, finally, traffic accidents. Other effects, that are relevant at the global rather than at the urban level, concern energy consumption, exhaustion of non-renewable energy sources and gas emissions (CO₂, CFC, CH₄, N₂O, O₃), which in turn contribute to climate change (Muñiz *et al.*, 2006).

3. Urban spatial structure and mobility

This paper can be placed in that strand of literature that has widely investigated the relationship between urban spatial structure and patterns of mobility, especially in the field of urban and transportation economics¹². Urban form influences individual travel behaviour and, as a consequence, the pattern of mobility within a city through several channels. Firstly, low-density areas are more difficult to be reached and served efficiently by a pervasive system of public transportation, mainly because of the lack of scale economies.

Secondly, the demand for public transportation tends to be lower in a dispersed city, especially where the distance to walk from home to public transport stations is so long that cars and motorbikes turn out to be more competitive. Besides, public means of transport are on average more time-consuming than private ones, especially in low-density areas¹³. In addition, the increase in average individual incomes has raised the opportunity cost of time-consuming (public) means of transport.

¹¹ See Anderson *et al.* (1996).

¹² See Gordon and Richardson (1997); Ewing and Cervero (2001); Camagni *et al.* (2002b); Giuliano and Narayan (2003). Regarding the Italian case, see Salatino (2006). See Banister (1997) and Cervero (2002) on the relationship between individual travel behaviour and urban form. A useful review on these topics can be found in Dieleman *et al.* (2002), Snellen *et al.* (2002).

¹³ This stylised fact has been found in most Italian cities. See Cirilli and Veneri (2009).

Urban dispersion, therefore, provides incentives to private means of transport use, through both a reduction of the demand for and a worsening of the supply conditions of public transport services.

The way in which urban spatial organization affects the patterns of mobility is quite complex. For instance, the role of compactness – as measured by residential density – is by no means unambiguous. On the one hand, the direct effect of high density could be a reduction in the distance travelled across the city (Giuliano, 1989), a better environment for walking, cycling and transit service as well as lower oil consumption (Newman and Kenworthy, 1989). In addition, high population density is positively correlated with the use of public means of transport (Camagni *et al.*, 2002a; 2002b; 2006).

Despite a great deal of research on this topic, the actual effect of density on travel behaviour is still not so clear, since density is often correlated with other relevant variables that affect travel behaviour, like functional diversity, income and intensity of mass transit use (Cervero and Kockelman, 1997). It is worth pointing out, moreover, that high density may result in a congestion externality (Anas *et al.*, 1998), which tends to be more severe in compact cities, where the bulk of commuting flows develops in a radial way towards the CBD. As a consequence, congestion could influence mobility by protracting the time spent travelling.

Mixité in land use is another important factor that seems to influence urban mobility¹⁴. The fundamental effect of a mixed land use is to narrow the citizens' circadian cycles, encouraging non-auto commutes for work and other purposes (Cervero, 1996). However, the effect of mixed land use on individual travel behaviour also depends on households' preference to live close to their workplace. This preference cannot be taken for granted in the high-income group of workers (Levine, 1998).

The patterns of mobility within a city could also be explained in terms of other features of spatial organisation, such as the degree of polycentricity and clustered development of a urban area (Tsai, 2001). The relationship, once again, is rather complex. Both a mono-centric and a poly-centric city, indeed, may turn out to be compact, albeit at different scales and in different ways. In smaller areas, the degree of monocentricity may go hand in hand with the degree of compactness. However, it may be the case that for larger (metropolitan) areas the most efficient spatial structure is compact *and* polycentric (Carrol, 1977; Edwards, 1977; Haines, 1986). As a city expands, a single centre becomes wider and wider and, consequently, more difficult to reach for an increasing number of people (especially for those who live in the suburbs). A polycentric city, by contrast, may be more accessible, providing it replicates the scale of a smaller and better organized city – especially if the various centres have developed in line with the existing public transportation infrastructure.

¹⁴ For an empirical investigation on the link between land use diversity and mobility in a single metropolitan area, see Pouyanne (2006). For a wider analysis of the relationship between mixed land-use and mobility see Frank and Pivo (1994) and Cervero (1996).

4. Mobility patterns in the Italian urban systems: a descriptive analysis

In this paper the patterns of mobility and their (environmental) impact have been explored within a sample of 111 Italian urban systems¹⁵. The units of analysis are local systems that can be considered functionally integrated and that turn out to function as cities, thus showing a relevant urban character. The functional integration of the systems is ensured by the use of the Local Labour Systems (SLL), defined by the Italian Statistical Office (Istat) on the basis of the commuting-to-work flows' self-containment (Sforzi, 1997). The urban character of the systems is captured, for simplicity, by the presence of a pivotal municipality with at least 50,000 inhabitants in 2001.

Before any attempt to measure the impact of mobility is made, it is worth looking at some broad tendencies that characterize the whole sample of the 111 Italian cities. Mobility, in particular, has been investigated taking into account only commuting-to-work flows *within* each urban system. This means that other commuting flows (e.g., for educational, consumption or recreational purposes) have not been considered. Likewise, commuting flows between cities have been ruled out, since the units in the sample are rather self-contained by definition and the interest is in the analysis of their internal organization.

Data on commuting-to-work mobility are drawn from Istat Population Census (2001). The cornerstone of the dataset is represented by the commuting-to-work flows between any pair of municipalities within each city. These flows are disaggregated by mode and duration of commuting, although more detailed levels of description might be available (e.g., sex of commuters). For each movement from one municipality to another – within the same urban area –, the point-to-point distance between their centroids has also been computed by the use of UTM coordinates.

First of all, the choice of the commuting mode is strongly biased towards the private means of transport, as suggested by a share of 89.4% over the total number of commuters (Tab. 1). Even ruling out those commuters that travel on foot, by bike or as passengers in a private car, this share is still high (68.9%). Hence, public transportation accounts for only 10% of total commutes and, among all the available options, only urban and trolley buses concentrate a significant share of mobility demand (5%), while rail transport is much less widespread. In addition, one may note that on average longer distances are travelled when public means of transport are used (12.3 Km as opposed to 9.7; Tab. 1)¹⁶.

Other relevant insights may be obtained by looking at the average commute duration, which strongly varies depending on the transport mode (private vs. public). Indeed, around 52% of public transport users spend 30 minutes or longer in their commuting movements, whereas 81.2% of private transport users spend less than 30 minutes (Tab. 2). This discrepancy may have a twofold explanation: on the one hand, commuters choose public means of transport when they have to travel longer distances. Public means of transport, however, could be relatively less efficient than private ones for a given distance, since commuting times do not necessarily reflect physical distances.

¹⁵ In this work 'city', 'urban system' and 'urban area' are intended to be synonymous, since the concept of city is declined as a cluster of municipalities that shows a high functional self-containment.

¹⁶ The distance expressed in kilometres is only an approximation of the actual distance travelled by commuters, the latter being surely higher than the point-to-point one.

Both factors can be expected to come into play. Indeed, when mass transit is used, it turns out that the average distance travelled by commuters directly increases with the time of commute, while this does not hold for private transport users¹⁷. When aggregating all the time intervals, the distance travelled on average is again longer if public means of transport are resorted to (47.7 Km as opposed to 43.8).

Tab. 1 Commuters and point-to-point distances by modes of commuting within Italian urban systems, 2001

Mode	Mode description	Commuters		Distance
		abs. val.	% val.	Km
1	Train	98,007	1.09	13.7
2	Tram	80,100	0.89	12.3
3	Underground	167,684	1.87	13.7
4	Urban bus or trolley bus	450,183	5.02	11.4
5	Extraurban bus or coach	107,566	1.20	12.2
6	School or business bus	50,940	0.57	10.8
	<i>Public transport</i>	<i>954,480</i>	<i>10.64</i>	<i>12.3</i>
7	Private car (driver)	5,557,294	61.93	11.0
8	Private car (passenger)	420,680	4.69	10.1
9	Motorbikes or scooters	624,071	6.96	9.5
10	Bikes, foot or other means of transport	1,416,359	15.78	8.4
	<i>Private transport</i>	<i>8,018,404</i>	<i>89.36</i>	<i>9.7</i>
		8,972,884	100.00	11.0

Source: our elaboration on Istat Population Census data (2001)

Tab. 2 Commuters and point-to-point distances by duration of commuting within Italian urban systems, 2001

Commuting times <i>minutes</i>	Public transport		Private transport*		Total*	
	<i>commuters, %</i>	<i>distance, Km</i>	<i>commuters, %</i>	<i>distance, Km</i>	<i>commuters, %</i>	<i>distance, Km</i>
0-15	11.6	9.8	50.9	8.5	45.9	18.2
15-30	36.3	11.4	35.1	10.9	35.3	22.3
30-60	42.0	13.1	12.6	13.0	16.3	26.1
> 60	10.1	13.4	1.5	11.4	2.5	24.8
	100.0	47.7	100.0	43.8	100.0	91.5

* private transport here does not include bikes and other means of transport

Source: our elaboration on Istat Population Census data (2001)

Tab. 3 Shares of commuters that use public means of transport by macro-area and population class, percentage values, 2001

	North	Centre	South	Islands
>400,000	16.0	17.3	13.6	6.7
200,000-400,000	6.1	4.2	4.2	5.5
100,000-200,000	6.1	3.2	4.7	2.6
<100,000	2.3	2.2	3.1	1.1

Source: our elaboration on Istat Population Census data (2001)

If one now investigates whether the share of public transport users varies depending on the location and population size of the urban systems, a few considerations may be made. Whatever the macro-regional area, the public share

¹⁷ In this case, it takes 45 minutes on average to travel the longest distance.

is increasing with population size (Tab. 3). On average, Northern systems show higher shares of public transport users than the others (especially those in the South and in the Islands).

Average commuting times have been also disaggregated by macro-regional areas (Tab. 4) and population classes (Tab. 5) of the urban systems, distinguishing in each case between private and public modes of transport. Table 4 shows that in Southern and Islands' cities, on average, the share of public transport users that travel for less than 30 minutes is higher than in Central and Northern Italy.

Tab. 4 Commuting times shares by mode of transport and macro-area, percentage values, 2001

Commuting times <i>minutes</i>	Public means of transport				Private means of transport			
	North	Centre	South	Islands	North	Centre	South	Islands
0-15	11.2	10.4	14.8	17.1	56.3	55.4	62.5	57.7
15-30	37.2	31.6	42.2	46.4	31.3	30.1	29.3	34.0
30-60	43.0	43.8	36.7	31.7	11.3	12.6	7.3	7.6
> 60	8.7	14.2	6.3	4.8	1.2	1.9	0.9	0.7
total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: our elaboration on Istat Population Census data (2001)

Tab. 5 Commuting times shares by mode of transport and population class (in thousands), percentage values, 2001

Commuting times <i>minutes</i>	Public means of transport				Private means of transport			
	> 400	200-400	100-200	< 100	> 400	200-400	100-200	< 100
0-15	8.5	24.0	27.1	36.0	47.0	65.8	70.5	76.9
15-30	33.8	48.8	48.2	41.9	34.4	28.8	25.7	19.9
30-60	46.1	24.3	22.1	18.0	16.6	4.9	3.4	2.6
> 60	11.6	3.0	2.6	4.1	2.1	0.5	0.4	0.6
total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: our elaboration on Istat Population Census data (2001)

5. Measuring the impact of mobility

This section focuses on the collective costs of different patterns of mobility. These costs are not measured directly, but other works in literature¹⁸ may help quantify the impact of commuting-to-work mobility, with the impact being a proxy for such costs (especially with respect to environmental costs due to air and noise pollution and to congestion).

Following the methodology proposed by Camagni *et al.* (2002a, chapter 3), an attempt may be made to transform the number of commuters in an impact-equivalent commuters (IEC) number, weighing each flow differently depending on the combination of transport mode and commuting duration. The rationale of this transformation is the following: public means of transport tend to be more sustainable from an environmental point of view, as opposed to private means. Each public means of transport, indeed, carries on average many more passengers than a private one, with a significant saving in energy and a reduction in polluting emissions. What is more, all public transport means (especially rail transportation)

¹⁸ See in particular Camagni *et al.* (2002a); Camagni *et al.* (2006).

make a smaller contribution to congestion. Secondly, the longer the commuting travel, the larger its impact in terms of both (air and noise) pollution and congestion¹⁹.

The impact indicator that would result following the methodology in Camagni *et al.* (2002a) is the following:

$$impact = \frac{\sum_{i,j,k} f_{ijk} w_{ij}}{\sum_{i,j,k} f_{ijk}} \quad (1)$$

where f_{ijk} indicates the flow of commuters in the k -th municipality of a given urban area that use the i -th transport mode and whose commuting duration is the j -th, whereas w_{ij} represents the weight attached to the combination of the i -th transport mode and j -th commuting duration.

Thus, although the impact indicator does not represent a direct measure of (environmental) collective costs due to mobility, it is a sound index that allows attributing a value to each city that turns out to be higher when mobility patterns are less sustainable (i.e., use of public means of transport is less intense and/or commuting times are longer).

The impact indicator that has been actually used in this work has been constructed following the logic of Camagni *et al.* (2002a), although distance replaces time in the weighting mechanism. In addition, transport modes (e.g. car, train, underground, bus, etc.) have been weighted on the basis of the estimated per passenger per kilometre CO₂ emissions, as reported in Amici della Terra and Trenitalia (2005) and showed in Table 6.

Tab. 6 Per passenger per Kilometre CO₂ emissions by transport mode

	gr CO ₂ /pkm
Train	35
Tram	32
Underground	21.3
Urban Bus	72
Extra-urban Bus	26
School or company Bus	31
Car	105
Motorbike	80
Bike, on foot, other	0

Source: Amici della Terra and Trenitalia (2005)

Commutes have been also weighted according to their point-to-point distances, rather than their time duration. In this way, indeed, it is possible to obtain an absolute measure of CO₂ emissions for the “typical commuter”. Moreover, the duration of commutes is somewhat an ambiguous measure, since a longer duration may reflect either a longer distance travelled or a less efficient mode of transport,

¹⁹ In the work of Camagni *et al.* (2002a; 2002b), however, a correction is made under the hypothesis that the impact of a commuting travel *per time unit* is decreasing with its duration. This can be due, according to the authors, to the fact that catalysed cars pollute more on departure and traffic is less congested outside the urban core. Also, trains stop less frequently when they travel longer distances.

given a certain distance. In other words, this alternative indicator does not include indirect information about congestion or different efficiency levels of the various means of transport. Rather, the focus is narrowed on the environmental implication of mobility patterns, in terms of global warming effects.

The impact indicator has been built as in formula (2). All commuting-to-work flows between any couple of municipalities within a city h – disaggregated by modes of transport – have been summed weighing the transport mode choice as in Amici della Terra and Trenitalia (2005) and also by the point-to-point distance between that couple of municipalities. This indicator reflects the level of per capita CO₂ emissions in each city and it is a direct measure of the sustainability of intra-urban mobility patterns:

$$impact = \frac{\sum_{i,j,k} f_{ijk} w_k d_{ij}}{\sum_{i,j,k} f_{ijk}}, \quad k=1,2...10; \quad (2)$$

where f_{ijk} represents the commuters-to-work within a given city that use the k -th means of transport and travel from municipality i to municipality j ; w_k is the weight attached to the k -th means of transport – as showed in Table 6 – and d_{ij} is the point-to-point distance between the i -th and the j -th municipalities.

The impact indicator has been then computed for each city. In Table 7 some descriptive statistics are shown, both at the sample and sub-sample levels. The variation range in the whole sample is between 240.8 (Castellammare di Stabia) and 2,475 (Roma). On average, the impact of mobility is lowest in Northern Italy and highest in the Islands and in Central Italy. One may also note that the indicator takes higher values in the small and medium sized urban areas, although the upper-medium cities “perform” better than the largest ones.

Tab. 7 Impact indicator: summary statistics over the whole sample of urban systems and over sub-samples by macro-area and population classes, 2001

	Obs	Mean	Std. Dev.	Min	Max
Italy	111	948.8	385.2	240.8	2475.0
North	28	685.6	164.7	452.8	1,078.6
Centre	39	1081.9	386.6	553.7	2,475.0
South	28	911.7	415.5	240.8	1,691.4
Islands	16	1150.2	358.9	385.5	1,794.3
> 400,000	17	954.7	439.8	452.8	2475.0
200,000 - 400,000	26	777.3	276.8	288.6	1256.9
100,000 - 200,000	47	991.1	358.8	240.8	1859.9
< 100,000	21	1061.8	462.3	385.5	1755.0

Source: our elaboration on Istat Population Census data (2001)

Cities have been then grouped by quartile classes of the impact indicator, as shown in Map 1. A look at the map confirms that, broadly speaking, the cities that fare worse with respect to the impact indicator may be found in Central Italy (especially in Lazio and in some areas of Tuscany and Emilia Romagna), as well as in the Islands and in some areas of Puglia.

Information about duration of commuting and point-to-point distances may be instructively combined in order to derive a simple indicator of relative competitiveness of the public transportation system (i.e., relative to the private motorized means of transport):

$$rel_public_comp_h = \frac{public_comp_h}{private_comp_h} \quad (3)$$

where:

$$public_comp_h = \frac{\sum_{i,j,t} f_{ijt}^{pu} \frac{d_{ij}}{T_t}}{\sum_{i,j,t} f_{ijt}^{pu}}, t=1,2..4^{20}. \quad (4)$$

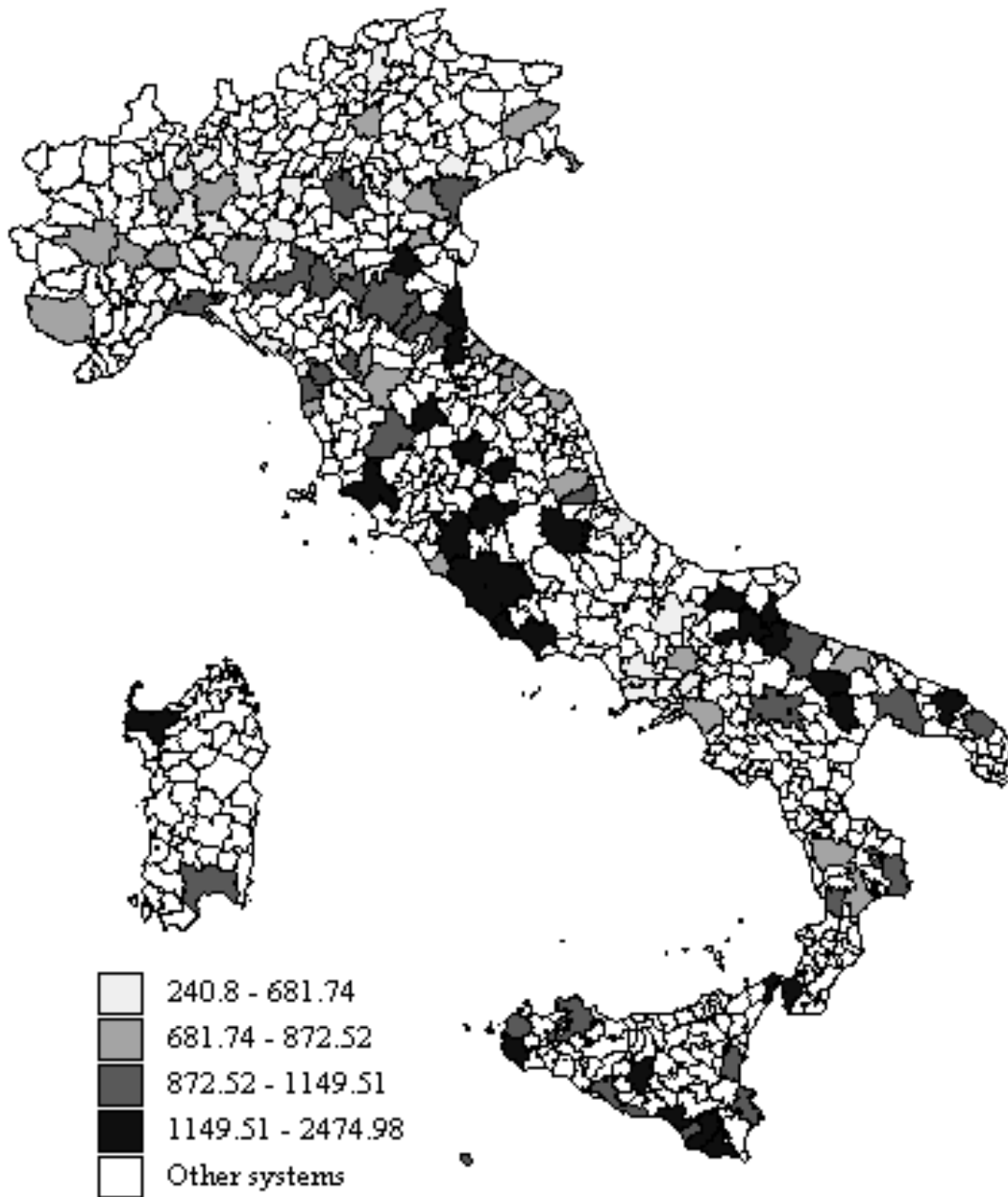
The numerator in formula (3) is computed as specified in (4): f_{ijt}^{pu} is the flow of mass transit users whose journey between municipalities i and j within the h -th urban system takes a travel time T_t . The ratio of the distance between the two municipalities over the corresponding average travel time is a proxy for the commute speed – and hence “competitiveness” – associated with that flow. To put it in another way, travel time over distance is a sort of congestion proxy (how long it takes to travel a given distance)²¹.

A look at the values of the relative competitiveness of the public means of transport from a territorial point of view (see Map 3 in the Appendix), shows that the largest concentration of virtuous cities may be found in the Northern and Eastern cities. It is quite interesting to note, in addition, that in some metropolitan areas (Rome, Turin, Bari and Palermo) the share of mass transit users tend to be rather high (see Map 2 in the Appendix) but this is not associated with a relatively more competitive public transportation system. More consistency between these two variables is observed, at the territorial level, in the Po valley and in Campania.

²⁰ In the Istat Population Census a duration of commuting equal to 1,2, 3 or 4 corresponds, respectively, to the following time intervals: 0-15 minutes, 15-30 minutes, 30-60 minutes and above 60 minutes.

²¹ Obviously, the denominator in formula (3) is computed in a completely analogous way for those commuters who travel by private means of transport.

Map 1 Italian urban systems by quartile classes of the impact indicator, 2001



Source: our elaboration on Istat Population Census data (2001)

The comparison between the *metropolitan areas* – for simplicity, those urban systems with more than 400,000 inhabitants in 2001 – suggests that the shares of commuters that use public means of transport are higher in Genoa and Milan (shares above 20%), followed by Rome, Venice, Naples and Turin (Tab. 8). Indeed, correlation between population and the share of public transport users is positive and rather high (0.637), indicating that the larger the city, the more developed the public transport system. Larger cities are more congested and concentrate a higher demand for public transportation, which allows the provision

of efficient (and more diversified) services, thanks to an adequate exploitation of the scale economies.

Commuting-to-work mobility tends to have a higher impact in Rome and some Southern cities like Taranto, Cagliari, Palermo and Catania, while Lombardy's cities – including Milan – show a relatively lower impact. Over the whole sample, the relative competitiveness of public transportation ranges from 0.53 (Brindisi) to 0.91 (Varese). Since in all the areas the value of this indicator is less than 1, public means of transport are anywhere more time-consuming than private ones for a given distance. Among the metropolitan areas, public transportation is relatively more competitive in the Lombardy's cities and in Verona.

Tab. 8 Population, area, density and mobility patterns in the urban systems with more than 400,000 inhabitants, 2001

	pop.	area	density	public_share	rel_public_comp	impact
Roma	3,374,511	3,657	922.8	0.199	0.609	2475.0
Milano	2,975,754	1,346	2,210.8	0.222	0.795	734.5
Napoli	2,235,602	565	3,956.8	0.170	0.707	675.1
Torino	1,684,336	1,874	898.8	0.165	0.681	855.5
Palermo	856,152	1,176	728.0	0.077	0.634	1079.1
Genova	723,633	926	781.5	0.267	0.617	1078.6
Bologna	723,366	2,046	353.6	0.115	0.641	972.2
Bergamo	705,872	902	782.6	0.041	0.726	492.7
Firenze	677,196	1,263	536.2	0.115	0.584	801.7
Bari	604,356	897	673.8	0.068	0.636	844.5
Venezia	600,549	1,206	498.0	0.170	0.579	958.6
Padova	580,466	981	591.7	0.052	0.659	686.2
Busto Arsizio	565,262	521	1,085.0	0.012	0.715	994.9
Catania	562,322	585	961.2	0.053	0.707	452.8
Verona	540,753	1,300	416.0	0.037	0.777	938.6
Cagliari	461,160	1,687	273.4	0.066	0.623	1065.7
Taranto	453,107	1,436	315.5	0.099	0.596	1125.0
Como	408,746	543	752.8	0.050	0.719	461.0
Brescia	407,887	539	756.7	0.056	0.733	679.3

Source: our elaboration on Istat Population Census data (2001)

6. The determinants of the impact: a regression analysis

In this section the determinants of the impact of mobility are explored. In particular, in the light of the survey that has been made in sections 2 and 3, such determinants are mainly put down to some variables related to urban spatial organization. The relevant explanatory variables are introduced in section 6.1, and a baseline cross-section econometric model is presented. The results of the estimation processes are then shown in section 6.2, and standard diagnostics is carried out.

6.1 Estimation framework

Different patterns of mobility, in the perspective proposed in section 4, may have different (environmental) impact intensity within the various Italian urban

systems. These patterns, in turn, may vary depending on how the urban systems are spatially organized. In this section, therefore, some variables are presented that may capture the spatial structure of the urban systems and may be interpreted as determinants of the impact²². The relevant variables might be grouped into four categories (Tab. 9).

Tab. 9 Variables related to urban spatial structure, urban dynamics and mobility patterns

INTENSITY-BASED SPRAWL VARIABLES		
<i>ldensity</i>	compactness of the system	log of residential density (population over total area) in 2001
SPATIAL-STRUCTURE SPRAWL VARIABLES		
<i>pivot_empl_share</i>	monocentricity of the system	pivot's share of total employment of the system in 2001
<i>gini_area_empl</i>	employment concentration	sum, for each municipality within a urban system, of the differences (in absolute value) between the share of total area and the share of total employment which that municipality concentrates with respect to the whole urban system (also see Tsai, 2005)
<i>gini_pop_empl</i>	functional diversity of the system	sum, for each municipality within a urban system, of the differences (in absolute value) between the share of total area and the share of total employment which that municipality concentrates with respect to the whole urban system (also see Tsai, 2005)
URBAN DYNAMICS		
<i>house_age</i>	recent house construction	proportion of houses built after 1982 over the total number of houses in 2001
MOBILITY PATTERNS		
<i>public_share</i>	transport mode choice	proportion of commuters that use public means of transport over the total number of commuters in 2001
<i>rel_public_comp</i>	competitiveness of the public means of transport relative to private ones in 2001	see formulas 3 and 4 in Section 4

All variables have been computed drawing on the Istat Population Census (1981, 2001) and the Istat Industry and Services Census (2001). While some variables are quite straightforward, others need some comments. First of all, residential density is an intensity-based variable of urban dispersion: the higher the density, the more compact the city. This variable has been rescaled in log terms (*ldensity*) in order to compress its extremely high variation range.

Secondly, three variables have been introduced in order to provide a direct description of the cities' spatial structure. The share of employment that is concentrated in the pivotal municipality is a measure of the degree of monocentricity of the cities. Then two concentration indexes *à la* Gini have been computed: one (*gini_area_empl*) is used to assess whether the employment in the systems is evenly distributed from a spatial point of view or concentrated in some sub-centres, as proposed by Tsai (2005). The other (*gini_pop_empl*) has been built as a proxy of functional diversity at the level of the whole urban system. When the latter index is close to zero, population distribution reflects employment distribution from a spatial point of view, implying a high level of *mixité*. The higher the index, the more either population or employment tends to concentrate within the system, delineating mono-functional sub-centres²³.

²² See Cirilli and Veneri (2009) for a wider analysis of the 111 Italian urban systems in terms of mobility patterns and spatial structure.

²³ See Tsai (2005) for an accurate analysis of sprawl measures and urban concentration measures in particular.

Thirdly, a couple of variables have been used to capture the recent dynamics of the urban systems. In particular, *house_age* highlights the proportion of recently built houses (i.e., after 1982) over the total number of houses in 2001. Thus, this variable is expected to take higher values in those systems where rapid urbanization processes have taken place in the last decades. The fourth group of variables includes the two mobility-related indicators that have been discussed in the previous section.

Before modelling the relationship between urban spatial structure and the impact indicator, some summary statistics are presented (Table 10), together with the correlation structure among all the relevant variables (Table 11). The impact of mobility tends to be lower in more compact and mono-centric cities, where public transportation is relatively more competitive and employment is less spatially concentrated (Table 10). The share of mass transit users is likely to be higher in more compact cities, whose employment is more spatially concentrated and urban dynamics have been less intense in the last twenty years.

Tab. 10 Summary statistics: mean, standard deviation and variation coefficient for all the relevant variables

	Obs	Mean	Std. Dev.	Min	Max
density	111	466.6	520.8	61.2	3,956.8
pivot_empl_share	111	0.650	0.176	0.140	0.974
gini_area_empl	111	0.405	0.166	0.019	0.765
gini_pop_empl	111	0.120	0.065	0.005	0.279
house_age	111	0.211	0.060	0.046	0.402
public_share	111	0.047	0.044	0.004	0.254
rel_public_comp	111	0.684	0.069	0.529	0.913

Source: our elaboration on Istat Census data (1981, 2001)

One may note, in addition, that the more intense the urbanization process since the Eighties, the lower the share of public transport users and the higher the intensity of private transport users. This may suggest that new settlements have been established in a discontinued way and not necessarily in line with the pre-existing public transport infrastructure. Its prospective positive influence over the impact via the transport mode choice is likely to be compensated by a distance effect. In newly urbanized settlements, perhaps, people use private motorized means of transport but travel shorter distances to their workplace on average (since they try to choose accommodation close to the latter). Clearly, this issue should be investigated further on empirical basis.

Tab. 11 Bivariate correlations

	impact	public_share	rel_pub_comp	house_age	ldensity	p_empl_sh.	g_area_empl.	g_pop_em
impact	1							
public_share	0.0258	1						
rel_public_comp.	-0.2845(**)	-0.125	1					
house_age	0.1112(*)	-0.413(**)	-0.085	1				
ldensity	-0.4882(**)	0.384(**)	0.133	-0.163	1			
pivot_empl_share	0.5164(**)	0.094	-0.220(*)	-0.209(*)	-0.264(**)	1		
gini_area_empl.	-0.2664(**)	0.371(**)	-0.044	-0.169	-0.088	-0.081	1	
gini_pop_empl.	-0.1484(*)	0.111	-0.008	0.206(*)	-0.178	-0.286(**)	0.492(**)	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed).

Source: our elaboration on Istat Census data (1981, 2001)

In the light of this preliminary analysis, the aim is to estimate an equation where the dependent variable – the impact indicator – is regressed on a few relevant variables of urban spatial structure. The hypothesis to be tested is that the impact of mobility within an integrated urban system may be explained to some extent by the patterns of mobility and the features of spatial organization – both on an intensity-based and a spatial-structure-based perspective.

The regression equation may be represented as follows:

$$\begin{aligned}
 \text{impact} = & \alpha + \beta_1 * \text{ldensity} + \beta_2 * \text{pivot_empl_share} + \beta_3 * \text{gini_area_empl} + \beta_4 * \text{gini_pop_empl} + \\
 & \beta_5 * \text{rel_pub_comp} + \beta_6 * \text{house_age} + \lambda_1 * \text{empl} + u
 \end{aligned} \tag{5}$$

where u is a stochastic error term with zero mean and constant variance. Given the correlation structure above, *ldensity* appears to be the most well-behaved variable among the intensity-based measures of spatial dispersion. The *pivot_empl_share* and *gini_area_empl* variables are included to assess the role of the spatial organization of the systems in determining the impact, while *gini_pop_empl* is intended to capture the effect of functional diversity. The baseline model also includes the relative competitiveness of public transportation among the obvious determinants of impact, as well as either *house_age* in order to control for urban dynamics. It is advisable to add a further control, given the high degree of heterogeneity of the Italian urban systems in the sample. One possible control may be the total employment of the urban system, to check for some scale effect.

6.2 Estimation results

To begin with, a robust standard errors OLS estimation of equation (5) has been made (Tab. 12)²⁴. All the main regressors turn out to be significant at either a 99% or a 95% confidence level, with the exception of *gini_pop_empl* that is not statistically different from zero. Thus functional diversity does not appear to exert a significant influence over the impact of mobility. In theory, a diversified territorial system tends to reduce home-work mobility. Nevertheless, if functional diversity is measured at the urban system level, the latter effect manifests itself especially in the flows between systems, which are not considered in this work.

²⁴ In order to better interpret the estimated coefficients, all the variables have been standardized (so as to have zero mean and unit variance).

This model seems to account for almost 68% of total variance, which appears to be quite a good result for a cross-section analysis. All the explanatory variables, indeed, show the expected signs: more compact cities are characterized by a lower impact of mobility, whereas the latter proves to be higher in those urban systems that are more mono-centric and whose employment is more evenly distributed over the territory.

This result could be a hint of a relative virtuosity of a poly-centric spatial organization of the cities, as opposed to mono-centric or dispersed cities. However, further analysis should be carried out in this field to get more insight into the efficiency of poly-centric spatial organization from a mobility perspective.

Regarding the relationship between the dependent variable and the urban dynamics in terms of house construction, it turns out that the higher the share of newly built settlements, the higher the impact of mobility. In addition, cities with relatively more competitive public means of transport tend to be characterized by a lower impact of intra-system mobility. Finally, the coefficient of the employment level is statistically significant, thus showing the presence of a (positive) scale effect on the impact.

Tab. 12 – OLS estimation of equation (5)

impact	Coef.	Rob. st. err.	t	P>t
ldensity	-0.604	0.074	-8.18	0.000
pivot_empl_share	0.379	0.065	5.83	0.000
gini_area_empl	-0.363	0.071	-5.10	0.000
gini_pop_empl	-0.013	0.052	-0.25	0.803
rel_public_comp	-0.147	0.052	-2.81	0.006
house_age	0.117	0.059	1.99	0.050
empl	0.508	0.171	2.98	0.004
const	0.000	0.054	0.00	1.000
Number of obs.	111		R-squared	0.697
F(7, 103)	31.20		Adj R-squar	0.676
Prob > F	0.00		AIC	197.6
BIC	219.3		HQC	206.4

Source: our elaboration on Istat Census data (2001)

Standard diagnostics has been then carried out. On performing an omitted variable test, the null hypothesis that the *gini_pop_empl* variable has a zero coefficient is not rejected, hence it can be dropped from the model. Now the (adjusted) R-squared indicator is 0.679 – compared to 0.676 in the baseline model – which represents a slight improvement. Besides, all three model selection criteria have improved. Regarding the model specification, the Ramsey test suggests that no unknown relevant variables have been excluded from the model. As far as the classical assumptions of the model are concerned, problems of multi-collinearity do not seem to arise, as well as problems of spatial auto-correlation of the residuals. Regarding the latter, the Moran’s *I* statistics has been computed for the residuals using three different matrixes of spatial weights. The results show that the model does not suffer from spatial dependence problems (see Table A1 in the Appendix)²⁵.

²⁵ The first weighting matrix (W1) is binary and is based on physical contiguity between spatial units. The second matrix (W2) is binary too and its generic element (W2)_{ij} is equal to 1 if the *i*-th city is one of the four

Dealing with the heteroskedasticity problem, robust standard errors have been used. The test of Szroeter (1978), however, suggests that the variable which tends to violate most the hypothesis of constant variance is *pivot_empl_share*. An alternative way to deal with heteroskedasticity, therefore, may consist in the estimation of a weighted least squares (WLS) model, where the weights are given by the inverse of that variable. Table 13 allows a comparison between the results of OLS (with robust standard errors) and WLS estimation of the reduced model. WLS estimates are consistent with the OLS estimates, as far as both the size and the sign of the coefficients and their statistical significance are concerned.

Tab. 13 Comparison of the estimation results under OLS and WLS methods (in italics the p-value associated to each variable)

<i>Variable</i>	<i>OLS</i>	<i>WLS</i>
const	0.000 <i>1.000</i>	-0.007 <i>0.912</i>
ldensity	-0.602 *** <i>0.000</i>	-0.634 *** <i>0.000</i>
pivot_empl_share	0.383 *** <i>0.000</i>	0.412 *** <i>0.000</i>
gini_area_empl	-0.369 *** <i>0.000</i>	-0.350 *** <i>0.000</i>
rel_public_comp	-0.147 *** <i>0.006</i>	-0.146 ** <i>0.017</i>
house_age	0.114 * <i>0.053</i>	0.127 ** <i>0.045</i>
empl	0.508 *** <i>0.004</i>	0.582 *** <i>0.000</i>
N. Obs.	111	111
Adj. R-squar.	0.679	0.664
AIC	195.7	158.905
BIC	214.6	177.871
HQC	203.4	166.599

Source: our elaboration on Istat Census data (2001)

Both OLS and WLS estimates of the reduced model confirm the finding showed in Table 12. Cities with a high-density structure are more sustainable in terms of per-capita CO₂ emissions, while cities with a strong mono-centric pattern of development – as well as cities with an even distribution of employment – show higher emissions. This finding could suggest a certain virtuosity of a poly-centric pattern of spatial organization, but further empirical investigation is needed. Moreover, a higher competitiveness of the public transport system is associated with a higher environmental sustainability of the cities, while the larger the city, the higher the distance that commuters have to travel – and, as a result, the higher the polluting emissions.

In order to check for the robustness of the estimation results, the econometric analysis has been carried out adopting, as dependent variable, alternative impact indicators. Such indicators have been constructed as in (2), while using different weighting systems to model the environmental impact of the different transport modes. More specifically, the modes of commuting have been weighted on the

nearest neighbours to city *j*. Finally, the generic element *ij* of the third matrix (W3) is the inverse of the distance among those spatial units which are located within a distance of 200 kilometres.

basis of PM₁₀ and NO₂ emissions, as reported in the work of Amici della Terra and Enea (2003 – p. 52). Indeed the results are consistent with those obtained with CO₂ weights, in terms of both signs and values of the coefficients (Tab. 14).

Table 14 OLS and WLS estimation: dependent variable weighted on the basis of alternative polluting gas emissions.

<i>Variable</i>	<i>OLS</i>	<i>WLS</i>
const	0.000	-0.006
	1.000	0.924
ldensity	-0.615 ***	-0.647 ***
	0.000	0.000
pivot_empl_share	0.368 ***	0.394 ***
	0.000	0.000
gini_area_empl	-0.369 ***	-0.351 ***
	0.000	0.000
rel_pub_comp	-0.145 **	-0.145 **
	0.006	0.019
house_age	0.133 **	0.149 **
	0.029	0.019
empl	0.494 ***	0.566 ***
	0.003	0.000
n. obs.	111	111
Adj. Squared R	0.68	0.66
AIC	195.9	159.5
BIC	214.9	178.5
HQC	203.6	167.2

Source: our elaboration on Istat Census data (2001)

7. Concluding remarks

Urban dispersion is by now a well-known phenomenon, whose definition is widely accepted and whose determinants and effects have been investigated at length, especially in the US literature. Nonetheless, the sub-urbanization and decentralisation processes that have contributed, in Europe and Italy too, to the formation of “dispersed cities” are inherently complex and difficult to measure accurately. In addition, analytical tools and quantitative measures borrowed from abroad do not necessarily suit the Italian experience.

The implications of a dispersed spatial organization are particularly difficult to evaluate. Indeed, while much literature has widely discussed the variety of costs that society incurs depending on the actual pattern of mobility and spatial structure of a city, the very measurement of such costs at the social, economic and environmental level is a long way from being satisfying. Likewise, an accurate comparison of the relative advantages and disadvantages (in terms of social welfare) that stem from the archetype of the “compact city” as opposed to that of the “dispersed city” is proposed in a number of studies. A lot of in-between situations, however, can be found in reality. Empirical measurement and testing is hence necessary to assess the efficiency and welfare properties of the different patterns of urban development.

Keeping in mind all these difficulties, this work is meant to explore the mobility patterns within the major Italian cities. Though the focus of the analysis has been narrowed to a specific type of mobility – commuting-to-work flows

within the systems –, an effort has been made to measure the environmental impact of mobility in the Italian cities. In particular, commuting flows has been weighted depending on the transport mode choice and the commute distance. The mobility impact, then, has been associated with some variables of urban structure and dynamics, in an effort to test empirically the hypothesis that mobility tends to be less sustainable in dispersed and less compact cities.

The cross-section econometric analysis confirms this assertion and the results seem to be quite robust after standard diagnostics. Further refinements are clearly needed to measure more accurately both the impact of mobility and the urban form of the cities. Future developments should be pursued with respect to the relationship between mobility and polycentric spatial organization and the analysis should be ideally extended to other types of mobility (home-school commuting as well as for consumption or recreational purposes). Nevertheless, this analysis appears to be a good starting point in the exploration of the Italian urban areas' mobility and in the study of the relationship between mobility patterns and spatial organization of the territory.

In addition, the past wave of deregulation in urban planning has contributed to the rapid formation of discontinued low-density settlements, often in the absence of a sound *ex-ante* evaluation of all the costs associated with this type of urban expansion – including non-private costs that can hardly be captured by free-market transactions – and of the degree of accessibility of the new dispersed areas, in the light of the pre-existing network of public infrastructure.

Urban planners should carefully assess the relative benefits and costs – both private and public – associated with the alternative patterns of urban expansion. In particular, they should beware of the environmental implications of a spontaneous (i.e., market-driven) process of discontinued and scattered urbanisation, especially if the newly developing areas cannot be efficiently provided with an adequate stock of public infrastructure and utilities.

References

- Altshuler A. (1997), "Review of the cost of Sprawl", *Journal of the American Planning Association*, No.43.
- Amici della Terra, Trenitalia (2005), *I costi ambientali e sociali della mobilità in Italia. Quinto Rapporto*, Amici della Terra.
- Amici della Terra, Enea (2003), *Valutazione del vantaggio, in termini di minori costi ambientali e sociali, di un forte sviluppo del trasporto collettivo in ambito urbano*, Amici della Terra – Enea.
- Anas A., Arnott R., Small K. A. (1998), "Urban spatial structure", *Journal of Economic Literature*, Vol. 36, n. 3.
- Anderson W. P., Kanaroglou P. S., Miller E. J. (1996), "Urban Form, Energy and the Environment: A Review of Issues, Evidence and Policy", *Urban Studies*, 33(1), pp. 7-35.
- Banister D. (1997), "Reducing the need to travel", *Environment and Planning B, Planning and Design*, n° 24, pp. 437-499.
- Brueckner J.K. (2001), "Urban sprawl: Lessons from urban economics", in: W.G. Gale, J.R. Pack (Eds.), *Brookings-Wharton Papers on Urban Affairs*, Brookings Institution, Washington, D.C., 2001, pp. 65-89.
- 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.

- Burton E. (2000), "The Compact City: Just or Just Compact? A Preliminary Analysis", *Urban Studies*, 37, pp.1969-2001.
- Calafati A. G. (2003), "Economia della città dispersa", *Economia Italiana*, n.1.
- Camagni R. (2002), "Città e qualità della vita: problemi e prospettive per le città italiane", *Economia Italiana*.
- 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., Gibelli M. C., Rigamonti P. (2002a), *I costi collettivi della città dispersa*, Alinea, Firenze.
- Camagni R., Gibelli M. C., Rigamonti P. (2002b), Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion, *Ecological Economics*, 40 (2), p.199-216.
- Carrol T. O. (1977), "Calculating Community Energy Demand", in R. J. Burby and A. F. Bell (Eds.), *Energy and the Community*, Ballinger, Cambridge.
- Cervero R. (2002), "Built environments and mode choice: toward a normative framework", *Transportation Research Part D*, 7, pp. 265-284.
- Cervero R. (1996), "Mixed Land-Use and Commuting: Evidence from the American Housing Survey", *Transportation Research A*, 30(5), 361-377.
- Cervero R., Kockelman K. (1997), "Travel Demand and the 3Ds: Density, Diversity and Design", *Transportation Research D*, 2(3), 199-219.
- Cirilli A., Veneri P. (2009), "Urban structure and mobility patterns: towards a taxonomy of the Italian urban systems", *Review of Economics and Statistics for Regional Studies*, No. 1 (forthcoming);
- Coleman A. (1985), *Utopia on Trial: Vision and Reality in Planned Housing*, Hillary Shipman, London.
- Cutler D. M., Glaeser E.L., Vigdor J.L. (1997), "The Rise and Decline of the American Ghetto" *NBR Working Paper* n° 5881.
- Delgado M. (1999), *El animal Público*, Ed. Anagrama, Barcelona.
- Deurloo M.C., Musterd S. (1998), "Ethnic Clusters in Amsterdam, 1994-1996: A Micro-area Analysis" *Urban Studies*, Vol 35, n° 3, pp. 385-396.
- Dieleman F. M., Dijst M., Burghouwt G. (2002), "Urban form and travel behaviour: Micro-level household attributes and residential context", *Urban Studies*, 39, pp. 507-522.
- Dubois-Taine G., Chalas Y. (1997) (Eds.), *La ville émergente*, Editions de l'Aube, Paris.
- Edwards J. L. (1977), "The effect of land-use on transportation energy consumption", in Burby R. J., Bell A. F. (Eds.), *Energy and the Community*, Ballinger, Cambridge.
- Elkin T., Mc Laren D., Hillman M. (1991), *Reviving the City: Towards Sustainable Development*, Friends of the Hearth, London.
- Ewing R., Cervero, R. (2001), "Travel and the built environment", *Transportation Research Record*, 1780, pp. 87-114.
- Florida R. (2002), *The rise of the creative class*, Basic Books, New York.
- Frank L., Pivo G. (1994), "Impacts of mixed land-use and density on the utilization of three models of travel: single occupant vehicle, transit and walking", *Transportation Research Records* 1466, pp.44-52.
- Giuliano G. (1989), *Relationships between Urban Form and Transportation: Implications for Long Range Planning* (DTFH61-89-P-00531): Federal Highway Administration.
- Giuliano G., Narayan D. (2003), "Another look at travel patterns and urban form: the US and Great Britain", *Urban Studies*, 40, pp. 2295-2313.
- Gordon P., Richardson H. W. (1997). "Are Compact Cities a Desirable Planning Goal?", *Journal of the American Planning Association*, 63(1), 95-106.

- Haines V. A. (1986), "Energy and Urban Form: A Human Ecological Critique", *Urban Affairs Quarterly*, 21(3), 337-353.
- Henry G. (2004) "La ciudad de baja densidad: lógicas, gestión y contención". *Consorti Universitat Internacional Menéndez Pelayo*, Barcelona, 24-26th November.
- Jacobs J. (1961), *The Death and Life of Great American Cities*, Random house, New York.
- Lattarulo P. (2003), *I costi ambientali e sociali della mobilità*, Franco Angeli, Milano.
- Levine J. (1998), "Rethinking Accessibility and Jobs-Housing Balance", *Journal of the American Planning*, 64(2), 133-148.
- Massey D., Denton N. (1993), *American Apperhaid: Segregation and the Uncerclass*. Cambridge, Harvard University Press.
- Massey D., Denton N. (1988) "Suburbanization and Segregation in U.S. Metropolitan Areas", *American Journal of Sociology*, n° 94 (3), pp.592-626.
- Mieszkowski P., Mills E.S. (1993), "The causes of metropolitan suburbanization", *Journal of Economic Perspective*, Vol. 7, n.3, pp. 135-147.
- Muñiz I., García M. A., Calatayud D. (2006), "SPRAWL. Definición, causas y efectos", *Document de Treball*, Departament d'Economia Aplicada, Universitat Autònoma de Barcelona.
- Musolino D., Guerzoni M. (2003), "Città dispersa e costi collettivi: il caso di Bologna", *Scienze Regionali*, n.1, pp.107-112.
- Naredo J. M., Carpintero O., Marcos C. (2003), "Los aspectos patrimoniales en la coyuntura Económica actual: nuevos datos e instrumentos de análisis", *Cuadernos de Información Económica*, n° 171.
- Newman O. (1972), *Defensible Space*, Macmillan, New York.
- Newman P. W. G., Kenworthy J. R. (1989), "Gasoline Consumption and Cities", *Journal of the American Planning Association*, vol. 55, pp. 342-346.
- Pouyanne G. (2006), "Land use diversity and daily mobility: the case of Bordeaux", *Scienze Regionali*, Vol. 5, No. 3.
- Salatino M. (2006), "La correlazione tra forma urbana e mobilità nei paesi dell'EU: un'analisi statistica", *Scienze Regionali*, Vol. 5, No. 3.
- Snellen D., Borgers A., Timmermans H. (2002), "Urban form, road network type, and mode choice for frequently conducted activities: a multilevel analysis using quasi-experimental design data", *Environment and Planning A*, 34, pp. 1207-1220.
- Szroeter J. (1978), "A class of parametric tests for heteroskedasticity in linear econometric models", *Econometrica*, Vol. 46, No. 6, November, pp. 1311-1327.
- Trilla C. (2001) "La política d'habitatge en una perspectiva europea comparada.", *Col.lecció Estudis Socials*, n° 9. Fundació "la Caixa", Barcelona.
- Tsai Y. H. (2005), "Quantifying urban form: compactness versus 'sprawl'", *Urban Studies*, Vol. 42, No. 1, 141-16.
- Tsai Y. H. (2001) *Travel-efficient urban form: a nationwide study on small metropolitan areas*; *University of Michigan Ann Arbor MI* – Dissertation.

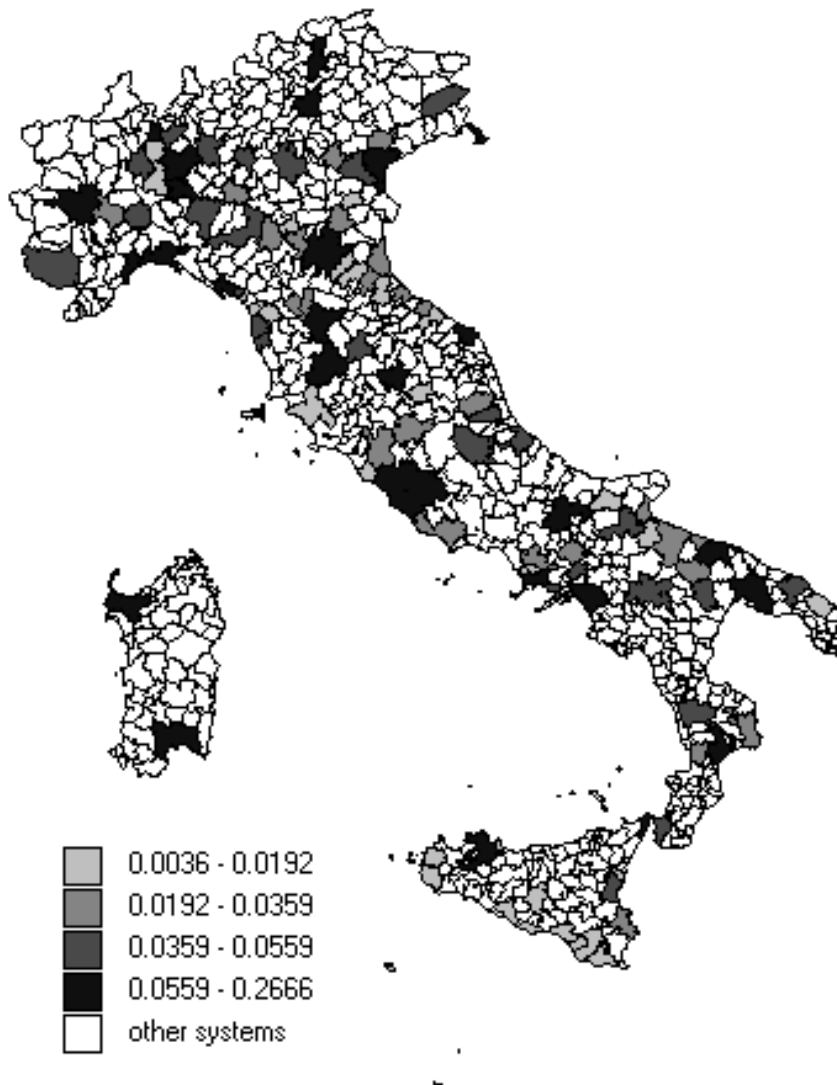
Appendix

Table A1: Moran's I statistics on OLS model (equation 5).

Weighting matrix	Moran's I	$E(I)$	$sd(I)$	z	p-value*
W1	0.049	-0.009	0.058	0.999	0.159
W2	0.066	-0.009	0.083	0.906	0.183
W3	0.059	-0.009	0.062	1.095	0.137

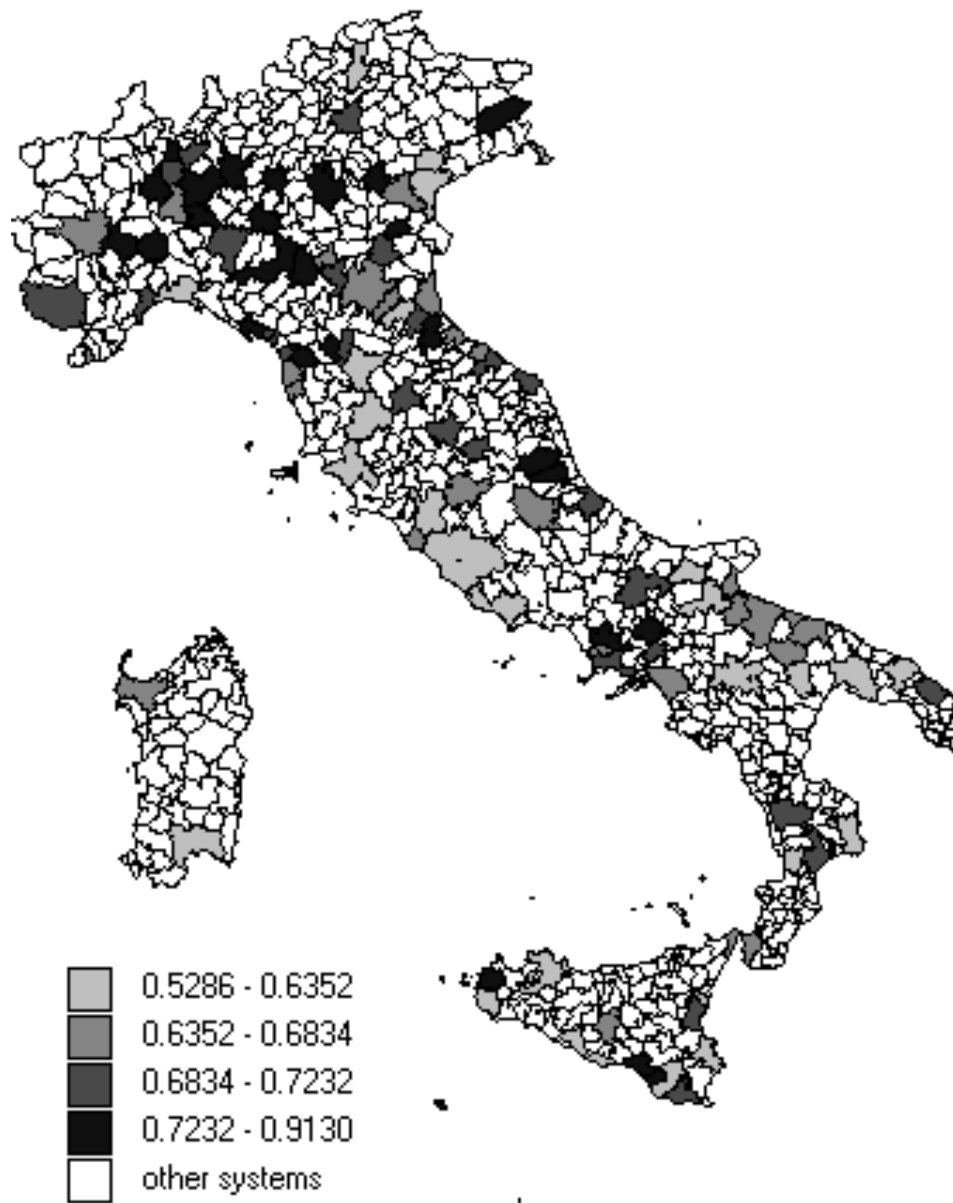
Source: our elaboration on Istat Census data (2001)

Map 2 Share of public transport users over the total number of commuters in each city, 2001



Source: our elaboration on Istat Census data (2001)

Map 3 Relative competitiveness of the public means of transport in each city, 2001



Source: our elaboration on Istat Census data (2001)