

# One or infinite optimal city sizes?

## In search of an equilibrium size for cities

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### Abstract

In this paper, the stylized assumption that one single 'optimal' city size exists for all cities - achieved when marginal location costs equal marginal location benefits - is abandoned, as well as the opposite view that each city operates on its own cost and production curves, defining a specific optimal size. Instead, this work maintains the comparability among cities and demonstrates that urban specificities in functions performed, quality of life, industrial diversity and social conflicts shift up and down the benefits and costs linked to pure physical size, leading to different 'equilibrium' sizes for cities.

In order to achieve this result, a model of equilibrium urban size is set up, based on urban costs and urban benefits, merging elements suggested both by the traditional urban economics literature as well as by updated approaches considering also environmental quality, urban form and inter-urban cooperation networks. The model is then estimated on a sample of 59 European cities with data at FUA level.

Empirical results allow the identification of city-specific 'equilibrium' sizes. The error term, i.e. the difference between actual urban population and the 'equilibrium' one predicted by the model can be explained by good or bad governance, thereby suggesting future strategies for more efficient urban planning.

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# 1. Introduction

In his seminal paper on “the economics of urban size” Alonso (1971) made two provocative but opposite propositions that puzzled and challenged scholars for many years. On the one side, he justified scientific research responding to the questions “how big is too big?” and “how big is big enough?”, opening a strand of empirical research on what was subsequently called the ‘optimal city size’ theory<sup>1</sup>. On the other hand, he presented the opposite view that optimality – in any sense – “will vary from city to city, from society to society” (p. 81), destroying the first research programme – except on a case-by-case basis – and the possibility of intervening normatively on the proper structure of a city system.

Richardson confirmed a “skeptic’s view”, underlining that an evident paradox existed between the theoretical acceptance of an “optimal city size” and the contradictory structure of urban systems in the real world. According to Richardson, this paradox could be explained with the existence of other determinants influencing urban agglomeration economies, beyond sheer physical size (Richardson, 1972).

Consequently, for a long time scientific efforts were redirected outside the problem of searching for an ‘optimal’ size and mainly dedicated to the identification of urban specificities that affect urban costs and benefits. Recently, this effort implied departing from the consideration of the pure physical structure and the pure indivisibilities that accompany the supply of services and the markets for inputs and output, and linking instead benefits and costs of city size to intangible elements of a different nature, impinging both on static and dynamic efficiency of cities through continuing information, innovation and knowledge acquisition.

In fact, two groups of reflections can be identified in this sense. The first group is more conventional, highlighting elements like quality of life, urban atmosphere, human capital, and agglomeration economies on the benefits side, and social conflicts/malaise, and costs of the city in general (urban land rent), on the costs side. These elements are closely correlated with city size, and influence its location benefits and costs. A second, more recent and unconventional type of literature encompasses the role of urban functions (embedded in dynamic urban models), the role of the city within inter-urban cooperation agreements (the so called city-network paradigm) on the benefit side, and the loss of efficiency and sustainability brought in by dispersed urban forms, on the costs side.

In this paper, an intermediate position is assumed between the idea of a single, ‘optimal’ size for any city and that of an infinite plurality of ‘optimal’, but unexplained sizes, one for each of them. Cities are assumed to be comparable, sharing common costs and benefits functions, therefore allowing cross-sectional empirical analyses and considering other determinants of urban benefits and costs beyond pure city size. Each city maintains its own specificity and unicity, and consequently is attributed its own ‘equilibrium’ size in an econometric model directly derived equating marginal costs and benefits to urban size. Both conventional and more innovative determinants of agglomeration costs and benefits are considered, merging economic, social, environmental and physical factors (urban form).

A similar paradox and theoretical challenge - one single vs. infinite urban sizes - was faced by the urban land use theory (the von Thunen - Alonso - Muth - Fujita trajectory), when it came to the issue of the structure of the entire city-system (the so-called “open city” model). In fact, the abstract equilibrium model, even in its more complex formulations, ended up with an urban landscape made of identical cities, with a single equilibrium - and optimal - size (Fujita, 1989, ch. 5; Camagni, 2011, ch. 3). The solutions proposed, though, leading to infinite city sizes, do not present the same theoretical level of the main model, and may look as ad hoc proposals.<sup>2</sup> The paper is structured as follows. First, the different views on the possibility of defining an

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<sup>1</sup> The optimal city size theory tackles the issue of optimal urban dimensions in terms of population; this is also the approach followed in this paper.

<sup>2</sup> Advocating a multiplicity of specialized cities, each with its own production function (as in Henderson, 1974 and 1985) looks as a rather ad hoc solution inside this kind of abstract models. On the other hand, showing urban heterogeneity as a consequence of a casual identity of urban production and cost functions, with increasing returns (as

optimal city size are presented in section 2; then different approaches concerning conventional and unconventional factors determining urban costs and benefits are critically summarized in Section 3. Next, these two types of determinants of urban size are separated from physical size and used in a new theoretical model as additional explicative variables of urban costs and benefits (Section 4). The model is then empirically tested on a sample of 59 European cities (Section 5 and 6). An ‘equilibrium’ city size for each single city of our sample is obtained and compared to actual size (Section 7); differences with respect to the equilibrium size are interpreted – beyond a sign of our ignorance - as the result of an efficient (un-efficient) urban governance and can suggest future strategies in urban planning.

## **2. The debate on ‘optimal’ city size: one single size or infinite sizes?**

Since the 1960s, urban economists and geographers focused on the problem of the optimal city size. A large consensus exists in the literature on the fact that some net increasing returns exist up to a certain urban size: beyond that size, opposite mechanisms are at work which translate positive externalities into negative ones, transforming economies into diseconomies. In this case, location costs increase, overcoming location benefits. As in the case of any other resource used in an intensive way, net decreasing returns to scale appear beyond a certain size.

The optimal condition for the entire population of the system, urban and not urban, is reached when urban marginal costs equal marginal benefits (to size increase). This condition represents the point of maximum local contribution to national income and should be assumed as a target by a national government interested in efficiency of the urban system (Alonso, 1971; Richardson, 1978). On the other hand, the size at which the difference between the curves of average benefits and costs is maximum corresponds to the (per-capita) optimal city size, an optimal situation from the point of view of the population already located in the city. Therefore, “optimal population will differ according to whether a national or a local viewpoint is assumed” (Alonso, 1971, p.72). In all cases, a social optimality is derived.

As all cities are assumed to operate with similar cost functions and production functions, the possibility opens up to give the floor to the real world, through empirical econometric analyses; but this implies the search for a single urban size, optimizing costs, or incomes or net urban benefits. And this goes against the common observation that shows a wide spectrum of city sizes, apparently in (a static or dynamic) equilibrium.

Therefore, over time, many criticisms arose against the optimal city size theory. These include the observations that cities perform different functions, are characterized by different specializations and consequently operate with different production functions (Henderson, 1974, 1985, 1996). In the words of Richardson: “we may expect the efficient range of city sizes to vary, possibly dramatically, according to the functions and the structure of the cities in question” (1972, pp. 30). In the real world, one would never expect the optimal position for each and every firm to occur at the same level of output; so why should one expect the optimal point in different cities to be identified at the same population level?

The bizarre fact is that Alonso himself was perfectly aware of this paradox, and, in fact, in his seminal paper (Alonso, 1971) made two provocative but at the same time mutually exclusive and antithetical propositions. On the one hand he justified the theoretical relevance of the question concerning the right size of cities (“how big is too big?”; and “how big is big enough?”), illustrated by his well-known graphic on urban costs and benefits, opening a wide field of empirical inquiries on ‘optimal’ city size. On the other hand, in the final

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in Fujita, 1985, p. 163), or as a consequence of the choice of different wage rates by different developers/managers of new towns, instead of the normal national wage rate (as in Fujita, 1985, p. 166), means relying on strange, casual cases rather than on theoretically relevant conditions. Introducing a consistent mix of urban externalities, quality public goods and rankings of services and functions into a modelling paradigm based substantially on the accessibility principle represents still a widely open theoretical challenge.

paragraph, he took the opposite view that cost and benefit curves (as those presented in the graphic) “will vary from city to city, from society to society” (p. 81). This second proposition definitely destroys the first research programme – except for a case-by-case approach – pointing out that different cities operate on different cost and production curves. What is even more worrying is that it jeopardizes the possibility of analyzing and interpreting the urban system from a normative point of view: “Admittedly (...) there is no suggestion here that a static general equilibrium approach can serve to model a nation’s system of cities because the movements of people, capital, ideas and institutional forms are slow and evolutionary, and while they change, other things are changing” (p. 82).

We are confronted here with two issues, of space heterogeneity and evolution on time. Concerning the first, it is clear that embracing urban specificities the scientific reflection is brought closer to the complexity of the real world, at a cost, though, of reducing comparability of cases and elegance of theoretical models. Similarly, concerning the time issue, possible heterogeneity of city sizes may be due to the different stages at which each city is found in its development pattern. In fact, optimal city size may change over time because of exogenous shocks, a different industrial composition and the ensuing growing income curve profile, and the introduction of new technologies, with the consequent falling transport prices (Partridge, 2010).

Inside the alternative between only one optimal size and infinite sizes, an intermediate, though abstract, solution is the one deriving from central place models. According to the different functional mix present in each urban rank and the different ‘range’ and ‘threshold’ attached to the market area of each function, higher rank cities are expected to show a wider size with respect to lower rank ones, while cities belonging to the same rank share the same size. Of course, this outcome derives from more recent central place models, like the Bechmann and McPherson one (1970), incorporating a demographic size for cities and market areas; in the earlier models of Christaller and Lösch in fact cities had no physical dimension, being defined only by a vector of presence/absence of different functions (Camagni, 2011, ch. 4).

As it will be explained later, this paper too proposes an intermediate solution, in a different sense with respect to central place models. Cities are supposed to share the same, complex cost and production functions with heterogeneous, substitutable factors linked not just to economic functions but to other context conditions. Therefore each of them maintains its specificity and consequently its ‘equilibrium’ size, but comparability (and possibility of running cross-sectional analyses) is saved and also possibility of devising policy strategies for urban growth or containment.

This proposal makes full use of a suggestion made by Richardson. According to it, the general paradox of city sizes could be explained with the existence of other determinants influencing urban agglomeration economies, beyond sheer physical size (Richardson, 1972). This indication redirected for a long time scientific efforts outside the problem of searching for an ‘optimal’ city size and towards the identification of urban specificities that affect urban costs and benefits, and consequently urban size – as will be shown in the next section.

### **3. The determinants of urban size**

#### **3.1 *Traditional approaches***

##### *Indivisibilities and productivity*

In the early approaches concerned with the economics of urban size, the reflection mainly concerned scale economies in the supply of private and public fixed capital and the provision of the consequent services and

on general productivity of the economic fabric. In some studies the optimal city size was even erroneously searched as the size guaranteeing the minimum location costs, with no attention for location advantages.<sup>3</sup>

Along this line, in the first part of the 1970s, theorization was accompanied by empirical studies mainly concentrated on the analysis of per capita expenses for public services (Ladd, 1992): Alonso and Mera estimated, on a sample of respectively American and Japanese cities, that per capita public expenses are greater for cities with more than one million inhabitants (Alonso, 1971; Mera, 1973).<sup>4</sup> Beyond that size, per-capita expenses increase, witnessing a U-shaped curve for average urban costs.<sup>5</sup> Hirsch showed that this rule was valid only for specific services (Hirsch, 1968), like firemen, while the average cost curve had either a constant shape with respect to urban size for some services, like education, or a decreasing functional shape, for others, like water, gas, electricity.

On the benefit side, a large body of literature emphasized the role of agglomeration economies as sources of productivity increases. Alonso showed that the average labour productivity is greater in American cities which have more than 5 million inhabitants, and demonstrates, like many others later, that the minimum of the location cost curve is achieved for an urban size smaller than the size guaranteeing the maximum of location advantages (Alonso, 1971). Through the estimate of an aggregate urban Cobb-Douglas production function on a sample of 58 American cities, Segal demonstrated that the parameter of the urban size variable was significant: metropolitan areas with more than 3 million inhabitants showed a factor productivity which is 8 per cent higher than the other cities (Segal, 1976). In a cross-sectional study on 230 American cities, Marelli achieved similar results: larger cities had a greater factor productivity than smaller cities, but this held up to a certain urban size, after which factor productivity showed again decreasing returns (Marelli, 1981). Other empirical studies found out that the productivity was 30 per cent greater in the Île de France and 12 per cent greater in Marseille, Lyon and Nice than in the rest of the French cities (Rousseaux and Proud'homme, 1992; Rousseaux, 1995).

### *Environmental costs and social conflicts*

On the cost side, a large literature tried to disentangle from the general urban location costs those costs specifically related to the natural environment (Anderson and Crocker, 1971; Clark and Kahn, 1989), to criminality and air pollution (Duncan, 1956), to environmental costs associated to urban size (Richardson, 1972). Hedonic price models became a diffused methodology to measure environmental costs and social conflicts - implicitly embedded in urban rent - and highly dependent on urban size (Ridker and Henning, 1967; Wilkinson, 1973; Freeman, 1971; Getz and Huang, 1978; Izraeli, 1987). The endogenous interaction with population and rent is tackled with a spatial econometric simultaneous regression model in Jeanty et al. (2010). They use Michigan census tract-level data and eventually find that local neighborhoods tend to register increases in housing values when gaining population, while on the contrary being more likely to lose population following an increase in housing values, controlling for spatial simultaneity, spatial interaction, and unobserved spatial autocorrelation in the data.

### *Agglomeration as a facilitator of social interaction*

As mentioned before, the benefits associated to agglomeration engender productivity increases. This aspect has been recently explained with the role played by density in creating an “urban atmosphere”. Density, in fact, enriches the probability of exchange of ideas, knowledge, and social interaction; all such elements are at the basis of greater productivity in agglomerated areas. A relatively recent wave of quantitative assessments found that pure density may explain up to half the total variance of output per worker (Ciccone and Hall,

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<sup>3</sup> Alonso stressed the mistaken tendency of many authors to look for “optimal city size” only by minimising the location cost function. As he argued, this would be sensible only if output per capita were constant (Alonso, 1971, pp. 70).

<sup>4</sup> Data presented by Alonso were previously analysed by Douglas, 1967.

<sup>5</sup> A doubt remains though with these results: in larger cities higher per capita expenses may be due to a higher willingness to pay for public services than to diseconomies of scale. Moreover, the difference in per-capita income between large and small cities exceeds the difference in average costs; therefore, if an optimal dimension exists, this is characterised more by productivity than by average costs.

1996). Proximity in a dense area may be conceived as a reducer of spatial impedance, therefore expected to raise the levels of efficiency of economic actors. Besides, firms may benefit from the relocation of other firms, being technologically compatible, in their proximity. Empirical evidence on this issue is provided in Martin et al. (2011). Also, this notion within the general spatial equilibrium approach à la Roback is behind Partridge et al. (2009), which deals with the spatial distribution of factor prices as influenced by various measures of remoteness. Incomplete access to the productivity gains accruing to firms and individuals in agglomerated areas is testified with a set of GMM estimates on US counties. The authors find, in analogy with the classical Central Place Theory, that median earnings and housing costs decline respectively 5% to 9% and 12% to 17% in remote areas as an average penalty across cities of different rank.

Agglomeration effects on wages are also divided between level and growth effects in Glaeser and Mare (2001). The authors find that coordination and learning may be at the roots of the wage increases accruing to workers relocating in dense urban areas. In this literature, level effects are those, stemming mainly from reduced transport costs, accruing to individuals (in terms of higher productivity, and hence, wages) relocating to urban areas. Growth effects are instead related to the faster wage growth characterizing individuals in urban areas. Both these effects attract knowledge workers to urban areas, which fosters cities' innovativeness, which in turn back-fires and causes a higher attractiveness of large urban areas to knowledge workers (Faggian and Mc Cann, 2008).

In addition to pure agglomeration effects, Glaeser and Mare (2010) show that sorting of skilled individuals in large urban areas may be a partial, but convincing, explanation of wage premia and higher productivity of urban workers and entrepreneurs. Interestingly, their empirical findings are valid only for very large urban areas, while medium and small cities seem to bring fewer advantages to people willing to relocate there.

#### *Urban diversity as source of creativity*

Moreover, a large body of literature addresses the large variety of externalities that result from the qualitative characteristics of the urban production environment. In 1961, Chinitz expressed some doubts about the fact that urban factor productivity depends mainly on the physical size of cities. He emphasised, on the contrary, the importance of a diversified and competitive urban production system as a source of urban efficiency and growth. Such a system is able to provide a far larger variety of externalities for small firms than an oligopolistic and specialised urban structure in which the internalisation of service functions inside large firms reduces urbanisation economies. Chinitz supported his thesis with an empirical analysis comparing New York, a large and diversified urban area, with Pittsburgh, a city highly specialised in monopolistic sectors; his findings supported the idea that in more diversified urban areas urban productivity depends on urbanisation advantages, while in more specialised cities it depends on economies of scale<sup>6</sup>. A similar view was expressed by Jacobs, who emphasized that it is not the mere physical proximity that generates economies of scale, but the diversity of activities located in large cities giving rise to higher creativity for people working and living in large cities (Jacobs, 1969).

A large debate was formulated in the literature whether industrial specialisation or diversification had a higher effect on urban productivity (Sveikauskas et al., 1988). In order to test for sectoral specificity, some studies estimated the size effects at the sectoral level. Through a CES production function, Shefer witnesses the existence of wide economies of scale in 10 sectors located in American cities (Shefer, 1973); Carlino divides the index used by Shefer in three parts, in order to capture economies of scale, economies of localisation and urbanisation in 19 manufacturing sectors, and finds significant results for both localisation and urbanisation economies in 12 industries out of 19 (Carlino, 1980). Sveikauskas estimates industrial labour productivity in 14 sectors, and finds that productivity increases by 6.4 per cent as city size doubles

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<sup>6</sup> Carlino (1980) provides a criticism of Chinitz' analysis, and demonstrates on a sample of 65 American towns that economies of scale, both internal and external to the firm, play a role in the definition of urban productivity. See on this debate also Kawashima, 1975.

(Sveikauskas, 1975). Moomaw comes to similar conclusions, with sectoral productivity increase associated to a doubling in city size equal to 6 per cent (Moomaw, 1983).

Recently, a microfounded general equilibrium model has been set up in Duranton and Puga (2001), which shows how cities can first host innovative firms, which produce prototypes (*nursery cities*). Then, firms find it optimal to relocate in lower rank cities in order to look for lower production costs and switching to mass production. This provides evidence to the Jacobs conjecture about the higher innovativeness of industrially-diversified cities.

### *Human capital and local synergies as sources of learning*

An important part of the literature deals with the role played by large cities as nursery of new ideas and seedbeds for learning processes, embedded in human capital and ‘tacit knowledge’ (Polanyi, 1966; Bathelt et al., 2004). When interpreted in dynamic terms, the urban environment supports cooperation, synergy and relational proximity which influence the innovativeness of firms. Shared values, common codes of behaviour, sense of belonging and mutual trust are features which the urban archetype shares with the *innovative milieu* archetype (Camagni, 1999), accounting for the ability to reduce uncertainty and generate processes of knowledge socialization and collective learning.<sup>7</sup>

### *Amenities as sources of urban attractiveness.*

More generally, “urban amenities”, in the form of accessibility to high quality public services (schools, hospitals), to a variety of recreational services (theatres, cinemas), to high education services (universities), to cultural capital (museum and historical monuments) (Clark and Kahn, 1988), have been highlighted as intangible advantages present in the large city (Clark and Cosgrave, 1991; Cropper, 1981; Henderson, 1982). Their economic assessment is usually based on hedonic price models (Herzog and Schlottmann, 1993; Wilkinson, 1973). Along this line, many studies devoted their efforts to measure the quality of life in urban areas (Berger et al., 1987; Blomqvist et al., 1988; Burnell and Galster, 1992; Conway and Liston, 1981; Liu, 1976; Roback, 1982 and 1988; Rosen, 1979; Carlino and Saiz, 2008) as source of attractiveness for firms and individuals. A recent empirical literature also identifies “consumption” amenities (e.g. nice weather: Rappaport, 2007; Cheshire and Magrini, 2006) as a source of urban attractiveness.

## **3.2 Unconventional approaches**

### *Urban functions and urban ranks*

The difference among cities in terms of urban functions was brought to the fore by Richardson in the 1970s, and formalized in a supply oriented dynamic model (SODY: Camagni et al., 1986). The model assumes that an “efficient” city size interval exists separately for each hierarchical rank, associated with rank-specific economic functions. In other words, for each economic function characterised by a specific demand threshold and a minimum production size, a minimum and a maximum city size exists beyond which urban location diseconomies overcome production benefits typical of that function.

As Figure 1 shows, under these conditions for each economic function and each associated urban rank, it is possible to define a minimum and a maximum city size in which the city operates under efficiency conditions (i.e. with net positive gains) (d1-d2 for the function - and centre - of rank 1; d3-d5 for the function - and centre - of rank 2; ...). The higher the production benefits (profits) of the single functions (increasing with rank), the higher the efficient urban size interval associated to such function.

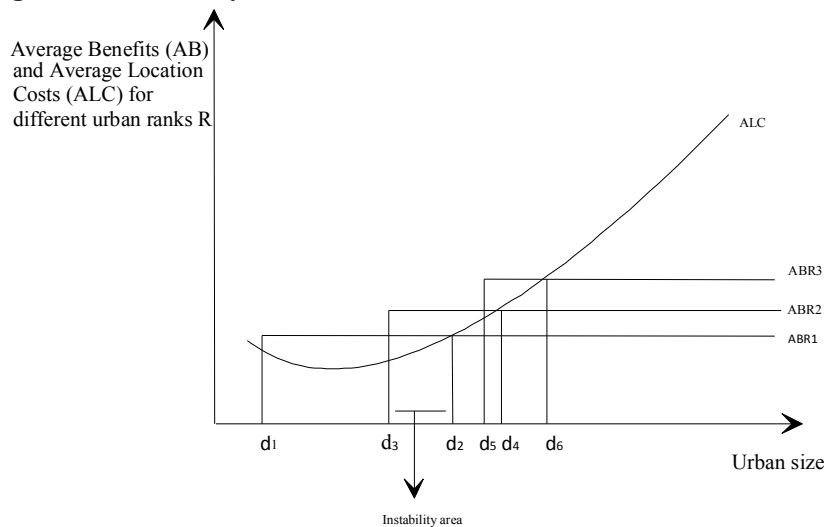
As each centre grows, approaching the maximum size compatible with its rank (‘constrained dynamics’), it enters an instability area (e.g. in d3-d2 in Figure 1) where it becomes a potentially suitable location for higher order functions, thanks to the achievement of a critical demand size for them. In dynamic terms, each

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<sup>7</sup> On the concept of *urban milieu* see Camagni, 1991. For empirical evidence on the existence of ‘urban *milieu* effects’, see Capello, 2001.

city's long term growth possibilities depend on its ability to move to higher urban ranks, developing or attracting new and higher-order functions ('structural dynamics'). This 'jump' is not mechanically attained: it represents a true urban innovation and is treated as a stochastic process in the dynamic model.

**Figure 1. Efficient city size for different urban functions**



Source: Camagni et al. (1986)

The interest of this model resides in the fact that it overcomes some of the limits of the 'optimal' city size theory, by suggesting:

- the need to replace 'optimal size' by an 'interval' within which the city size is 'efficient'<sup>8</sup>, i.e. where average production benefits exceed average location costs;
- the need to allow different 'efficient' urban sizes according to the functions actually performed by the cities;
- the possibility of decoupling urban ranks from urban size. Differently from Christaller's approach, two cities of the same size (for example, size  $d_2$  in Figure 1) can belong to two subsequent ranks (1 and 2 in the example), depending on their capacity to attract/develop higher functions.<sup>9</sup>

A recent contribution (Duranton and Puga, 2005) provides indeed evidence on the increasing pattern of functional, rather than sectoral, specialization in US cities, with an impressive concentration of managerial functions in large urban areas and a symmetric pattern of concentration in production plants in smaller cities.

### City networks

Born in the field of industrial economics (Chesnais, 1988), the concept of network behaviour has been transferred into urban economics providing a successful theoretical framework to overcome the limiting interpretative power of the traditional central-place model<sup>10</sup>. In fact, real city-systems in advanced countries have deeply departed from the abstract Christaller pattern of a nested hierarchy of centres and markets, showing (Camagni, 1993):

- processes of city specialization and presence of higher order functions in centres of lower order;
- horizontal linkages between similar cities, not allowed in the traditional model (e.g. the financial network among top cities in the worldwide hierarchy or linkages among similar centres performing headquarter and advanced services functions (Camagni and Capello, 2004).

<sup>8</sup> Richardson (1972) suggests replacing the concept of optimal city size with an efficient interval of urban size in which urban marginal benefits are greater than marginal location costs.

<sup>9</sup> The two cities will differ, though, in dynamic terms: the one belonging to the lower rank (R1) will not grow further, having reached the maximum size of its interval, while the one having developed the higher functions (linked to rank 2) will grow, due to the presence of new and wide net urban benefits (profits).

<sup>10</sup> Camagni (1993) theorised the concept applying it to urban systems. The same concept was already utilised in other fields, such as the behaviour of the firm and macroeconomic organisational behaviour. For a review of the concept, see Capello and Rietveld (1998).



This empirical evidence supported the idea that new and increasing relationships among centres follow a network logic, where specialisation patterns are the main reasons to establish economic relationships. While the organisational logic underlying Christaller's central place model is territorial, emphasising a gravity-type control over market areas, in the network model a different logic prevails, based on long distance competition and co-operation, regardless of the distance barrier (Camagni, 1993). While in the more traditional analysis, transport costs and economies of scale were the principal forces shaping the spatial organisation of functions and cities, in the new logic other elements come to the fore - economies of vertical and horizontal integration, and network externalities similar to those emerging from "club goods". These elements provide the possibility for cities to reach higher critical mass and scale economies through a network integration – in the economic, logistic and organizational fields – with other cities.

Two main typologies of city networks are considered: linkages among centres of similar size performing different functions, aiming at the achievement of economies of vertical integration, division of labour and market size ('complementarity networks') and linkages among centres performing similar functions aiming at the achievement of economies of horizontal integration and network externalities ('synergy networks') (Camagni, 1993).

The city-network model allows single cities to upgrade their economic functions without necessarily increasing their individual size. Therefore cities of intermediate size are being increasingly looked upon as the places that could well host the growth of the years to come: limited city sizes, in fact, facilitate environmental equilibrium, efficiency of the mobility system and the possibility for citizens to withhold a sense of identity, provided that a superior economic efficiency and scale economies are reached through cooperation networks with other cities – located in the same regions or distant but well connected.

Urban productivity was empirically found to be much more closely related to urban connectivity - another concept similar to urban network relations – than to urban scale (McCann and Acs, 2011), thus supporting the global city argument.

The joint application of the SOUDY model and the city-network paradigm has relevant implications for urban efficiency and growth: size is not the only determinant of factor productivity and agglomeration economies. Presence of higher urban functions and integration inside city-networks are also extremely important elements in the explanation of the competitive advantage of cities, allowing to boost productivity even in presence of limited urban sizes.

### *Urban form and sprawl*

A different recent research program concerns the inspection of urban form and its relevance for the efficiency of cities. In this case, urban form is 'optimal' when it allows cities to grow in physical terms with the lowest social and environmental costs and the maximum social and economic benefits. A dispersed urban form, in fact, increases environmental costs associated to higher mobility on private cars, easily generates social segregation and limits inter-personal interaction. Unfortunately such sprawling models are spreading in many advanced and developing countries (Breheny, 1992; Owens, 1992), following the American pattern. A land consumption index calculated by the French *Agences d'Urbanisme* shows that between 1950 and 1975 in 22 French urban areas population has doubled while the territory occupied has increased only by 20-30%; however, between 1975 and 1990 population has increased by 25% while the territory occupied by urban activities has doubled (Camagni, 1999). Other studies have calculated the collective cost of urban sprawl; in the Lombardy region, in the Milan metropolitan area, for example, an analysis on 186 municipalities shows the "wasteful" character of sprawling development patterns in terms of land consumption, public costs for infrastructure and services and collective, environmental costs linked to urban mobility (Camagni *et al.*, 2002).

International institutions like the European Commission and OECD have long since pointed out the economic and social costs of sprawl, while more recently the European Environment Agency (EEA, 2006) has indicated urban sprawl as the a crucial but up to now unmet and ‘ignored‘ challenge.

In theoretical terms, it looks justified to hypothesize urban form as a necessary qualification and complement to urban size in the determination of urban efficiency.

#### 4. A model for equilibrium city size

In this work, the tangible and intangible elements highlighted by the literature as sources of urban development and size are used in an equilibrium model of urban size, which finds its roots in the neoclassical stream of location choice models à la Von Thünen-Alonso-Fujita. In this class of models, the location choice of single individuals (firms) are driven by utility (profit) maximization achieved when marginal location costs equal marginal location benefits (Alonso, 1960; Muth, 1969; Fujita, 1989).<sup>11</sup>

The following implicit total urban cost function is assumed, where total location costs depend on the physical size of the city (*size*), and the intangible aspects highlighted by the literature, namely social costs (*malaise*), costs due to dispersed urban form (*sprawl*) and in general, the costs of the city, captured by urban land rent (*urban rent*):

$$C = f(\text{size}, \text{rent}, \text{malaise}, \text{sprawl}) \quad (1.)$$

In turn, total benefits are made dependent on the physical size of the city (*size*), on the intangible aspects highlighted by the conventional literature - namely quality of life (*amenities*), creativity (*diversity*), urban atmosphere (*density*) - and by the unconventional one – namely quality of economic functions performed (*functions*) and inter-urban networks (*networks*), an equilibrated urban system (*urbansystem*) - as in the following implicit function:

$$B = f(\text{size}, \text{amenities}, \text{diversity}, \text{density}, \text{functions}, \text{networks}) \quad (2.)$$

Physical size acts on both costs and advantages, and is therefore a dual concept, representing a joint source of positive as well as negative externalities for city dwellers.

A standard Cobb-Douglas specification for both functions is adopted. This specification is more tractable than most others, and allows to avoid the implausible assumptions about the elasticity of the function’s arguments (Uzawa, 1962).

Equations (1.) and (2.) therefore, become, respectively:

$$C = \text{size}^{\alpha} \text{rent}^{\beta} \text{malaise}^{\delta} \text{sprawl}^{\gamma} \quad (3.)$$

and

$$B = \text{size}^{\kappa} \text{amenities}^{\zeta} \text{diversity}^{\theta} \text{density}^{\chi} \text{functions}^{\mu} \text{networks}^{\nu} \quad (4.)$$

In order to increase the tractability of the model and without losing generality, each parameter is assumed to be bounded in the interval (0,1). The exception is represented by the size exponent in the cost function ( $\alpha$ ), which, à la Alonso, is hypothesized to be larger than one, reflecting an exponential cost function with respect to size. Analytically, these assumptions lead to the following conditions:

---

<sup>11</sup> The controversial issue concerning the capability of a pure market mechanism to lead to an optimal allocation of population in cities - evident in the stylized theoretical model of urban land use but not confirmed by more complex formulations with externalities and public goods (Henderson, 1985, p. 262; Fujita, 1989, p. 284) - is not crucial for the model presented here.

$$\frac{C}{size} = \alpha size^{\alpha-1} rent^{\beta} malaise^{\delta} sprawl^{\gamma} > 0, \quad (5.)$$

$$\frac{C}{size} = \alpha(\alpha-1) size^{\alpha-2} rent^{\beta} malaise^{\delta} sprawl^{\gamma} > 0$$

and

$$\frac{B}{size} = \kappa size^{\kappa-1} amenities^{\zeta} diversity^{\theta} density^{\chi} functions^{\mu} networks^{\nu} > 0, \quad (6.)$$

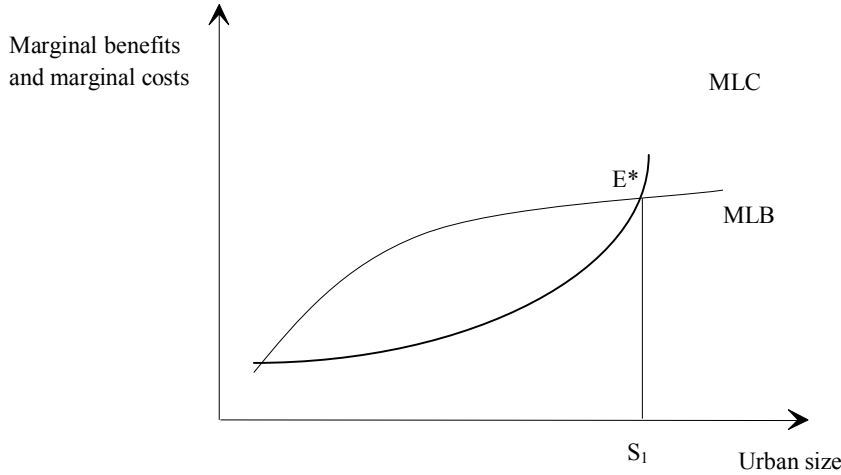
$$\frac{B}{size} = \kappa(\kappa-1) size^{\kappa-2} amenities^{\zeta} diversity^{\theta} density^{\chi} functions^{\mu} networks^{\nu} < 0$$

With these assumptions, marginal costs and benefits are well-behaved with respect to the traditional optimal city size theory, and have the expected shape as represented in Figure 2.

This model is closed by assuming spatial equilibrium across the urban system. As people can freely move across space in order to look for better living conditions (i.e. they can look for cities characterized by higher benefits or lower costs), in equilibrium the city must satisfy the condition in which marginal location costs equal marginal benefits (MLC=MLB), thus maximizing utility of people, profits of firms and aggregate national efficiency. The assumption of spatial equilibrium across European countries may attract criticism. For instance, Cheshire and Magrini (2006) find that it may hold at most only within EU countries. However, recent empirical work (e.g. Rappaport, 2004) provides the theoretical rationale for the fact that “*even very small frictions to labor and capital mobility along with small changes in local productivity or local quality of life suffice to cause highly persistent population flows*” (Rappaport, 2004, p. 554).

The equilibrium condition is represented in point E\* in Figure 2.

**Figure 2. Equilibrium size of the city.**



Analytically, this implies the following condition:

$$\frac{C}{size} = \frac{B}{size} \quad (7.)$$

i.e.

$$\alpha size^{\alpha-1} rent^{\beta} malaise^{\delta} sprawl^{\gamma} = \kappa size^{\kappa-1} amenities^{\zeta} diversity^{\theta} density^{\chi} functions^{\mu} networks^{\nu} \quad (8.)$$

which in turn implies:

$$\frac{size^{\alpha-1}}{size^{\kappa-1}} = \frac{\kappa}{\alpha} \frac{amenities^{\zeta} diversity^{\vartheta} density^{\chi} functions^{\mu} networks^{\nu}}{rent^{\beta} malaise^{\delta} sprawl^{\gamma}} \quad (9.)$$

that is:

$$size^{\alpha-\kappa} = \frac{\kappa}{\alpha} \frac{amenities^{\zeta} diversity^{\vartheta} density^{\chi} functions^{\mu} networks^{\nu}}{rent^{\beta} malaise^{\delta} sprawl^{\gamma}} \quad (10.)$$

Eq. (9.) can be log-linearized in order to obtain an estimable function. This process yields to the following functional form:

$$(\alpha - \kappa) \ln(size) = \ln \left( \frac{\kappa}{\alpha} \right) + \zeta \ln(amenities) + \vartheta \ln(diversity) + \chi \ln(density) + \mu \ln(functions) + \nu \ln(networks) - \beta \ln(rent) - \delta \ln(malaise) - \gamma \ln(sprawl) \quad (11.)$$

and finally:

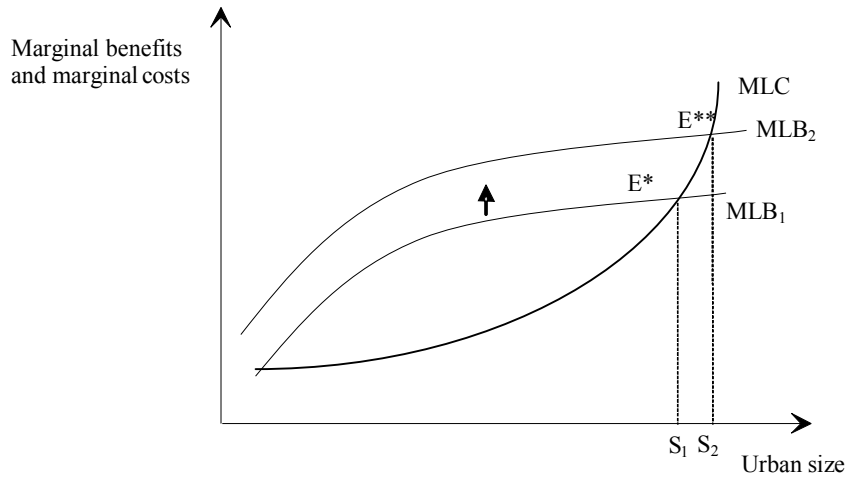
$$\begin{aligned} \ln(size) = & \frac{\ln\left(\frac{\kappa}{\alpha}\right)}{(\alpha - \kappa)} + \frac{\zeta}{(\alpha - \kappa)} \ln(amenities) + \frac{\vartheta}{(\alpha - \kappa)} \ln(diversity) + \\ & + \frac{\chi}{(\alpha - \kappa)} \ln(density) + \frac{\mu}{(\alpha - \kappa)} \ln(functions) + \frac{\nu}{(\alpha - \kappa)} \ln(networks) + \\ & - \frac{\beta}{(\alpha - \kappa)} \ln(rent) - \frac{\delta}{(\alpha - \kappa)} \ln(malaise) - \frac{\gamma}{(\alpha - \kappa)} \ln(sprawl) \end{aligned} \quad (12.)$$

Eq. (12.) shows that the equilibrium size of the city, and in particular the physical equilibrium size of the city, depends on city-specific characteristics.<sup>12</sup> Conventional elements like amenities, human capital, industrial diversity, and unconventional elements, such as the presence of high-level functions and urban networking, can act as “shifters”, moving upward the marginal benefit function and achieving, *coeteris paribus*, a physical equilibrium size at E\*\* (Figure 3a). On the other hand, elements like sprawl, social conflicts and high urban rents can push upward the marginal location costs, reducing the physical equilibrium size to E\*\*\* (Figure 3b).

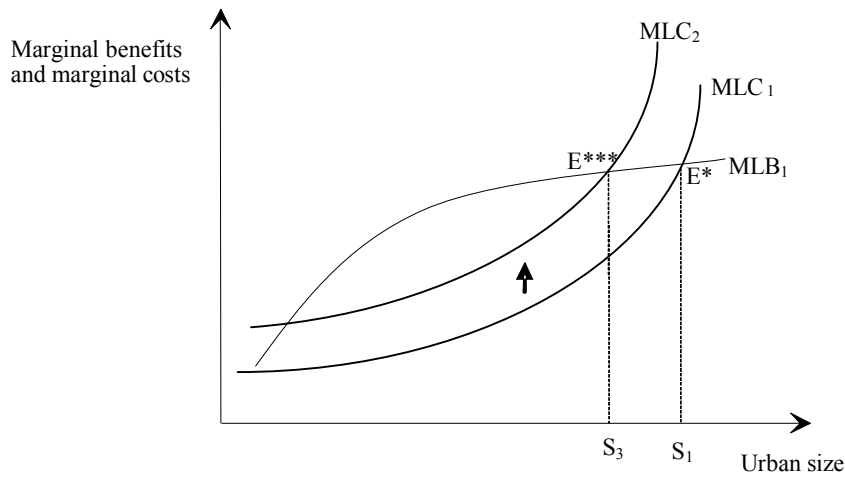
### Figure 3. Different equilibrium sizes according to urban characteristics

a. Vertical shifters on the marginal location benefits

<sup>12</sup> A similar result in a different theoretical context was achieved by Fujita (1989, p. 151) treating “the open city model with absentee landowners” inside the land use equilibrium theory. Assuming two cities with two communities maximizing their utilities, with similar productivity curves but, in one case a superior level of amenities, the model proves that the city with amenities, being more attractive, reaches a higher equilibrium size (which is also optimal). This result shows that a convergence between our approach and the one of the New Urban Economics.



*b. Vertical shifters on the marginal location costs*



While for the conventional elements there is a large consensus on the decision whether they impact on costs or benefits, for the unconventional elements guesses are made on the fact that sprawl represents a costs, with a notable exception in Glaeser and Kahn (2004), and high level functions and networking act instead on benefits. Their real effects will be empirically tested by estimating eq. (12.) using traditional econometric models, and find the elasticity of the equilibrium size to each single urban feature. The estimated equilibrium sizes for each city can be compared to the actual population, in order to reveal whether in reality each city of the sample exceeds (or is lower than) its equilibrium size. The result – represented by the econometric residual – can be explained by an inefficient (efficient) urban governance, and can shed light to strategies of urban planning (see Section 6).

## 5. The sample and the data set

Our empirical test of the model in eq. (12) is based on a set of 59 Larger Urban Zones, EUROSTAT's definition of the concept of a Functional Urban Area. This choice is mainly motivated by data availability, since the data set merges information from two main sources, viz. EUROSTAT and the ESPON project "Future Orientations for Cities" (FOCI, 2010).

Figure 4 represents the city sample employed in this analysis, well diversified between Eastern and Western, capital and non-capital, Northern and Southern European cities: 22% of cities in the sample lie in New

Member States; 37% of total city sample is a capital city.<sup>13</sup> Besides, as of 2010, this sample covers 26% of the total EU27 population; 36% of total EU27 urban population; 33% of total GDP produced in the European Union; 29% of total labour force; and 32% of total labour force employed in the tertiary and advanced industries.

**Figure 4. City sample**



Source: EUROSTAT

The novelty of the database is related to its geographical coverage, which allows to control for institutional (national) effects, as well as to the territorial unit of analysis. Data are in fact collected at the Functional Urban Area (henceforth, FUA) level. The definition of FUA is based on EUROSTAT calculations, whereby FUAs are defined as “Larger Urban Zones” (LUZ).<sup>14</sup> LUZ define cities “on the basis of daily commuting

<sup>13</sup> Capital cities in the EU27 countries are 22, as Brussels, Dublin, Valletta, Nicosia, and Luxembourg are excluded from the sample because of missing values.

<sup>14</sup> “The LUZ approximate as much as possible the functional urban region taking into account the commuting of the work force into the core city. The LUZ are built as follows:

1. The *building blocks* for the LUZ are the Local Area Units (i.e. communes). However, not always data is available for the LAUs and in some cases NUTS level 3 regions were used as building blocks.
2. The *commuting rate* is calculated as the share of the out commuters of the working population. The commuting rate threshold for including or excluding areas of the hinterland in the LUZ is set between 10-20%.
3. Criteria of spatial contiguity helped in adjusting the definition of the LUZ although some exception was made.

The definition of the LUZ is then adjusted taking into account the requirement of spatial contiguity. Moreover, it should be underlined that the boundaries of all LUZ were developed in close cooperation with national experts of the country concerned. This approach assures that realistic choices were made, paying attention to the view of experts who know the city in question very well” (EUROSTAT, 2010).

flows between one or more core areas and the surrounding territories” (EUROSTAT, 2010). In EUROSTAT, these areas are mostly defined according to a country-specific strategy based on merging smaller administrative areas (See Appendix 1 for details).

Table 1 presents a summary of the data set built for the empirical analysis.

Both urban benefits and costs are classified according to their more conventional or unconventional consideration in the literature, as summarized in Section 3. For what concerns *traditional urban benefits*, among the multiple urban factors considered in the literature, this paper focuses on:

urban amenities, proxied by the inflows of tourists in the Metropolitan Area representing a measure of urban attractiveness;

the Jacobsian source of externality stemming from a diversified labour market, calculated as the share of non top 5 industries (at NACE 2 digits) in total employment (Glaeser et al., 1992);

finally, a measure of agglomeration economies, measured as population density, including the vertical development of the metropolitan area (and therefore the pure probability of “contagion” of new ideas).

For what concerns *nonconventional urban benefits*, among elements previously only seldom covered by empirical studies on the determinants of urban size, in the following are considered:

city-networks, proxied by the number of Framework Programme 5 projects to which institutions of Metropolitan Areas jointly participate over the LUZ workforce;

high level urban functions, measured as the share of the labour force in ISCO professions 1 and 2 (respectively legislators, senior officials, managers and professionals);

Along the same lines, urban costs can be classified according to whether their role is properly and structurally described in previous studies, and, consequently, well tested in applied works, or whether their inclusion presents elements of novelty.

**Table 1. The variables, the indicators and their sources.**

Type of variable	Class of variable	Variable	Measure	Years	Source of raw data
<b>Dependent</b>	Physical size of cities	Size	Population levels in 59 LUZ (1)	Average 2004-2006	ESPON/Urban Audit
	<i>Traditional urban benefits</i>				
	Quality of life	Amenities	Tourist inflows over available years	Average 2001-2004	Urban Audit
	Urban creativity	Diversity	Sectoral diversity index measured as 1 - the share of top 5 NACE 2 digits industries (2)	1990	ESPON
	Agglomeration economies	Density	Population density	Average 1989-2003	Urban Audit
	<i>Traditional urban costs</i>				
<b>Independent</b>	Cost of the city	Rent	Cost of average quality apartment per square meter	Average 1991-2004	Various (see Appendix 2)
	Social conflict	Malaise	Number of crimes per 1,000 population per year	Average 1989-2003	Urban Audit
	<i>Nonconventional urban benefits</i>				
	City networks	Networks	Number of participations in Framework Programme 5 projects over labour force	Average 1998-2002	CORDIS
	High level urban functions	Functions	Workforce in ISCO professions 1 and 2 (respectively, legislators, senior officials and managers and professionals) over total FUA labour force (2)	Average 2002-2004	ESPON
	<i>Nonconventional urban costs</i>				
	Diffused urban form	Sprawl	Percentage of non-built-up area of the total area of FUA. Built-up areas include artificial areas according to the CORINE Land Cover nomenclature.	1990	ESPON

(1) “The larger urban zone (LUZ) is an approximation of the functional urban zone centred around the city” (from EUROSTAT).

(2) Data for this index are collected at NUTS2 level, and rescaled at the FUA level according to the ratio of FUA population/NUTS2 population.

*Traditional urban costs* include:

the pure location costs associated to urban size, as indicated by land rent (measured with the prices per square meter of average quality apartments in downtown metropolitan areas<sup>15</sup>);

the social distress associated to urban life, captured by the number of crimes recorded for the FUA;

*Nonconventional urban costs* take into account the notion of sprawl, which is here measured with the percentage of non-urbanized land inside FUA. This indicator captures the degree of fragmentation of a FUA territory, typical of a dispersed urban form.

All variables, following the theoretical model above outlined, are in natural logs.

## 6. Empirical results

### 6.1 OLS estimates

Table 2 shows the estimation results of the main model described in Section 3. Across all regressions, robust standard errors are employed, in order to correct for likely heteroskedasticity in the data, provided the likely relevance of country-specific effects. Most estimated parameters show remarkable stability across the whole table, suggesting the substantial absence of multicollinearity, thereby improving parameter identification. In fact, the only parameter which consistently changes sign as more regressors are added is land rent. This result is easily explicable by the fact that this variable is jointly linked both to benefit as well as to cost elements, and that adding benefit variables to the explanation of equilibrium city size allows urban rent to capture only the costs of the city (models 4-6, Table 2).

**Table 2. Empirical results for estimating eq. (12.).**

Dependent variable: equilibrium city population	(1)	(2)	(3)	(4)	(5)	(6)
Constant	8.80*** (1.49)	12.54*** (1.57)	11.05*** (1.49)	3.93*** (2.70)	1.58 (2.29)	9.93*** (2.01)
Land rent	0.70*** (0.20)	0.43** (0.18)	0.36** (0.17)	-0.12 (0.15)	-0.15 (0.12)	-0.35** (0.14)
Malaise	-	-0.16* (0.09)	-0.16** (0.08)	-0.12* (0.06)	-0.11** (0.05)	-0.10* (0.05)
Urban amenities	-	-	-	0.47*** (0.07)	0.43*** (0.07)	0.32*** (0.07)
Urban diversity	-	-	-	1.69** (0.68)	2.05*** (0.57)	0.83* (0.46)
Density	-	-	0.27*** (0.10)	-	0.26*** (0.07)	-
City networks	-	-	-	-	-	0.12** (0.05)
Urban functions	-	-	-	-	-	0.20** (0.09)
Dummy small countries	-	-	-	-	-	-0.25* (0.13)
Dummy financial capital	-	-	-	-	-	0.60*** (0.17)
Sprawl	-	-0.37*** (0.10)	-0.20** (0.09)	-0.29*** (0.07)	-0.21*** (0.08)	-0.30*** (0.08)
R <sup>2</sup>	0.20	0.39	0.45	0.70	0.75	0.78
Joint F test	12.51***	13.31***	12.73***	37.56***	32.67***	21.01***

<sup>15</sup> See Appendix 2 for more details.



Robust standard errors	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	59	59	59	59	59	59

Notes: Dependent variable: Equilibrium city size (Log city population 2004-2006). Standard errors in parentheses.  
\*\*\*, \*\*, \* imply significance at 10, 5 and one percent, respectively.

Results show a remarkable adherence with theoretical ex-ante expectations. If the spatial equilibrium assumption holds, and people are, with some limitations, free to move and search for better life conditions, these estimates provide a reliable first-layer assessment of urban size determinants in the European urban system.

The first model presents a simple regression where the equilibrium size is explained by land rent, which captures a synthesis of all costs and advantages of city size. Results show a significant and positive relationship between land rent and equilibrium city size; land rent is therefore in this case an indicator of net urban advantages.

When both conventional and unconventional costs of urban size are inserted in the regression, the results have the expected negative and significant sign (Model 2), while urban rent still keeps a positive sign even if it loses significance.

In order to capture the determinants of urban size, a first synthetic indicator of urban advantages is added to the regression, that of density which should conceptually include agglomeration economies (Model 3). The results indicate that a higher density is a source of higher equilibrium sizes, as always claimed by the literature.

An additional interesting step is to better identify “agglomeration economies” through different sources of urban advantages. Models 4 and 5 present the results once density is substituted or accompanied, in the regression, by diversity and amenities; both variables are significant and related positively to equilibrium urban size. Model 5 shows that the more generic density variable is still significant, suggesting that other elements are still embedded in a dense urban form, providing advantages to a large city.

Model 6 presents the whole specification of eq. (12), since the two unconventional variables, city-networks and high level urban functions, are added to our estimate. Moreover, model 6 controls for the likely distortion introduced in the analyses by ignoring out-of-ordinary city-specific characteristics that may further enhance, or be detrimental to, the capability of cities to reach a larger equilibrium size. First, a dummy variable for small countries (viz. all countries in the sample but Germany, France, Spain, Italy, Poland, and the UK) is introduced, allowing to control for two differentiated modes of development, where small countries are characterized by an urban system with smaller cities. Results show that in fact smaller countries present lower equilibrium city sizes, *coeteris paribus*.

Second, in model 6 a dummy for financial cities is added (including London, Paris, Frankfurt, Madrid, and Milan). Also in this case empirical analysis proves the validity of the ex-ante intuition: cities hosting a relevant stock exchange benefit from an extra premium in size terms with respect to cities with identical characteristics. Model 6 embraces all variables of the theoretical model (12.) plus the last two dummy variables: the main conclusions on all relevant variables hold, while the two dummy variables simultaneously used further improve the linear fit of the model (78% of total variance explained). Therefore, model 6 is chosen as the most representative one throughout the remaining of the paper.

In sum, results show that (Table 2):

agglomeration economies, generically measured by urban density, do matter;

traditional views on urban advantages, linked to diversity and amenities, increase the explicative power of the model ( $R^2$ ) from 45% to 70%;

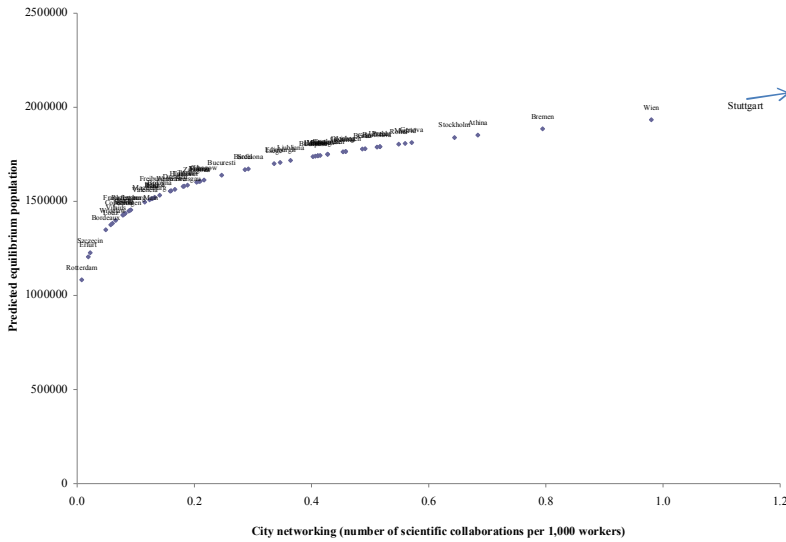
most recent non-conventional views on urban growth, pointing out the relevance of new elements like the presence of economic and power functions and participation to an urban network, are

corroborated: these elements allow cities to achieve equilibrium at higher sizes, withstanding the higher urban costs implied. The conclusions of the SOUDY model and the city-network theory are confirmed: the explicative power of the present model is enhanced;

land rent, after netting out its relations with other benefit and cost variables, is the single highest cost for urban population, reflected in the highest parameter estimate within the final model (6).

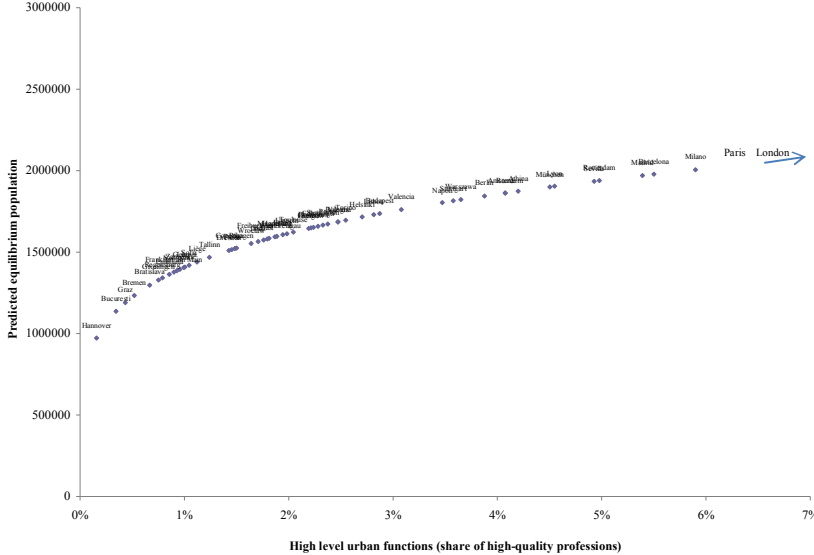
In order to deepen the analysis on the role of unconventional variables, an inspection of how equilibrium city size changes with increasing levels of functions and city-networks is carried out. Results of such calculations are shown in Figures 5 and 6. Both Figures show that, *coeteris paribus* (i.e. when cities hypothetically share identical characteristics other than networking and high-level functions), both elements allow higher equilibrium sizes, but at decreasing rates.

**Figure 5. Predicted equilibrium population for different levels of city networking.**



Source: authors' calculations.

**Figure 6. Predicted equilibrium population for different levels of high level urban functions.**



Source: authors' calculations.

## 6.2 Identification of causal relations

As the results presented above may be affected by reverse causality, i.e., population increases determining a rise in urban costs and benefits, a twofold econometric strategy was adopted. First, standard techniques were

used in baseline OLS regressions, imposing a time lag to the dependent variable: population is measured as an average 2004-2006, whereas all independent variables have been calculated for antecedent years.<sup>16</sup>

Secondly, a solid approach to causality identification is adopted, with the use of instrumental variables. Among all independent variables, malaise (crime rates) and the share of high level urban functions are likely to be more heavily at risk of reverse causation. In fact, crime rates are often found to be higher in large urban agglomerations (Glaeser and Sacerdote, 1999) and high-level urban functions are typical of large urban agglomerations (Clark, 1945).

In Table 3, model 6 is replicated (column 1) and the crime and urban functions variables are instrumented in sequence (columns 2 and 3).

**Table 3. Instrumental variable estimates.**

<i>Dependent variable: equilibrium city population</i>	(1)	(2)	(3)
Constant	9.93*** (2.01)	12.79*** (3.17)	12.78*** (2.48)
Land rent	-0.35** (0.14)	-0.32** (0.13)	-0.41*** (0.17)
Malaise	-0.10* (0.05)	-0.24* (0.14)	-0.20*** (0.07)
Urban amenities	0.32*** (0.07)	0.29*** (0.07)	0.21*** (0.07)
Urban diversity	0.83* (0.46)	0.88** (0.45)	0.80** (0.39)
City networks	0.12** (0.05)	0.10** (0.05)	0.13** (0.06)
Urban functions	0.20** (0.09)	0.13 (0.08)	0.46* (0.25)
Dummy small countries	-0.25* (0.13)	-0.22* (0.12)	-0.17 (0.16)
Dummy financial capital	0.60*** (0.17)	0.46* (0.24)	0.62** (0.23)
Sprawl	-0.30*** (0.08)	-0.27*** (0.07)	-0.22** (0.09)
R <sup>2</sup>	0.78	0.82	0.75
Joint F test	21.01***	22.97***	37.40***
Number of observations	59	59	59
Variable instrumented	-	Malaise	Functions
Instruments used	-	Social capital indicators, time-lagged per capita FUA wealth.	Social capital indicators, indicators of a culturally advanced society, presence in the FUA of at least one university among the top 500 in the 2003 Shanghai ranking.
Partial R-squared of excluded instruments	-	0.13	0.14
Cragg-Donald statistic	-	9.08** (0.02)	9.14** (0.04)
Anderson corr. LR statistic (identification/IV relevance test)	-	8.45** (0.04)	8.50* (0.08)
C-statistic for exogeneity	-	5.30* (0.07)	6.43** (0.04)

<sup>16</sup> Country fixed effects have also been used, although these results are not presented in this paper. They strongly confirm the main message of the paper, without however adding much insight into the main relations between independent and dependent variables.

*Notes: Dependent variable: Equilibrium city size (Log city population 2004-2006). Standard errors in parentheses. \* = \*\*\*, \*\*, \* imply significance at 10, 5 and one percent, respectively.*

The instruments are chosen as to be correlated with the potentially endogenous regressor, but not with city population. Crime levels are instrumented with time-lagged social capital indicators, and a lagged per capita GDP level as a measure of richness. Recent studies demonstrate in fact, both theoretically as well as empirically, why higher levels of social capital should be correlated with lower crime levels (Akçomak and ter Weel, 2008). Social capital acts as a non-legal constraint to deviations, via informal sanctioning, altering the incentives of agents – costs and benefits - to actually commit offenses (Becker, 1968); moreover, richer and older societies are expected to have lower crime rates.

Social capital characteristics are summarized by urban values of generalized trust, percentage of volunteering, overall interest in politics, percentage of tax cheating, percentage of petition signing and attitude towards change. For the present elaborations, these variables have been, for the first time to our knowledge, calculated by aggregating at the urban level individual answers to the 1990 wave of the European Values Survey (EVS) questions.<sup>17</sup>

High level functions are present in culturally-advanced and rich societies, that do not necessary reside in large cities. High level urban functions are therefore instrumented with the degree of trust among individuals of a society and the openness of a society to modern values.<sup>18</sup> Finally, a further instrument is the presence in the FUA of at least one university in the top 500 2003 Shanghai ranking;<sup>19</sup> while several such high-level educational institutions are located outside the largest metropolitan areas, they certainly correlate with the share of workers employed in high-level professions.

Results of the instrumental variables regressions confirm the main message from the previous section. The theoretical model holds even after controlling for reverse causation. As Table 3 shows, both malaise (the crime variable) and urban functions remain significant and with the right signs once instrumented.

As for the instruments' validity, we run the usual battery of tests, whose results are shown in the bottom part of the Table. First, the partial  $R^2$  of the instruments is shown. This represents the percentage linear variance due to the selected instruments in the first-stage auxiliary regression. In both cases, a remarkable 13/14 per cent of total variance is explained with our instruments.

In the second block, the Cragg-Donald statistics (Cragg and Donald, 1993) is shown. This statistic tests the null hypothesis of under-identification of the matrix of the regressors/instruments  $Q_{XZ}$ . It is distributed as a  $X$  square (indeed, it can be reconduced to a Wald test (Baum et al., 2003). Since in both cases the null hypothesis is rejected (at the 95% confidence level for both crime and functions), we can safely infer that the instrumental variables regressions are not under-identified.

The third block in the bottom part of Table 3 shows the Anderson LR statistic, which represents an instrumental variables relevance test. Once again the test demonstrates (at the 95% and 90% confidence level for crime and functions, respectively) the validity of these instruments as tools to exclude reverse causality in these relations.

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<sup>17</sup> The EVS is a comprehensive survey on Europeans and their beliefs about broad life categories, including trust, religion, politics, and society. Citizens have been asked, respectively, "Would you agree that most people can be trusted?", "Do you spend some [spare] time in voluntary organizations?", "Is politics important in your life?", "Would you justify cheating on taxes?", "Have you ever signed a petition for political action?", and "How do you react to a major change in life?". For more information on data collection methods see [www.europeanvaluesstudy.eu](http://www.europeanvaluesstudy.eu).

<sup>18</sup> In particular, for the latter variable, the answers were used to the questions "Is casual sex justifiable?", "Do you think that a woman has to have children in order to be fulfilled or is this not necessary?" and "If a woman wants to have a child as a single parent but she doesn't want to have a stable relationship with a man, do you approve or disapprove?". On the other hand, trust is measured as the percentage of people replying that they highly trust connationals.

<sup>19</sup> Raw data are available at <http://www.arwu.org/ARWU2003.jsp>.

Finally, the last block of tests in the bottom part of Table 3 shows C statistics for both instrumental variables regressions. This statistic demonstrates that the instruments are also exogenous with respect to the variable being instrumented, which is a crucial condition for the instrument validity.

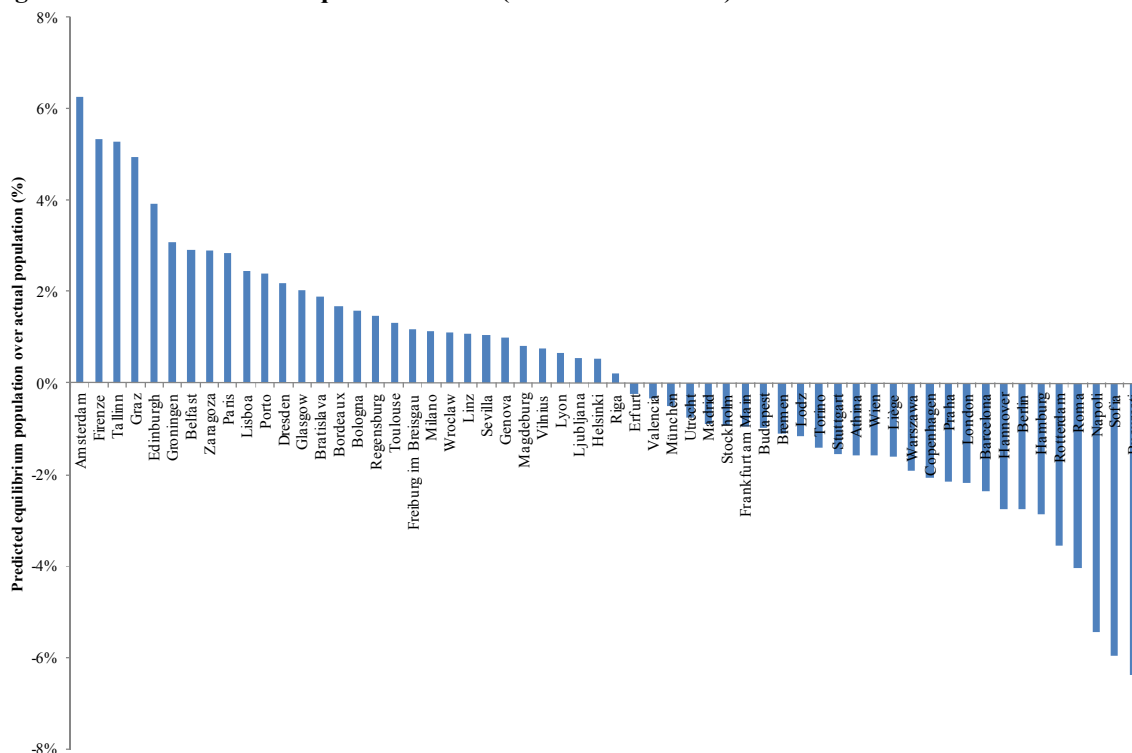
The use of country fixed effects, a time-lagged value for the dependent variable, and instrumental variable techniques, safely allow to conclude that reverse causation does not represent a major issue in our results. Although in the long run exogenous shocks to any urban size determinant may indeed cause circular causation (i.e., a shock in crime rates may reduce equilibrium city population, thereby reducing crime rates), results in this paper suggest that the theoretical micro-foundations of the model of equilibrium city size hold to the empirical test.

## 7. City specific variability

The results of the model may be further exploited, by comparing the city population predicted by the model and the actual population for each FUA; this allows the identification of cities beyond (or below) their theoretically-determined equilibrium size. In this whole section, all Figures are based on the results obtained on Model 6 in Table 2, which, as above mentioned, has been chosen as the most convincing linear estimate of the theoretical model.

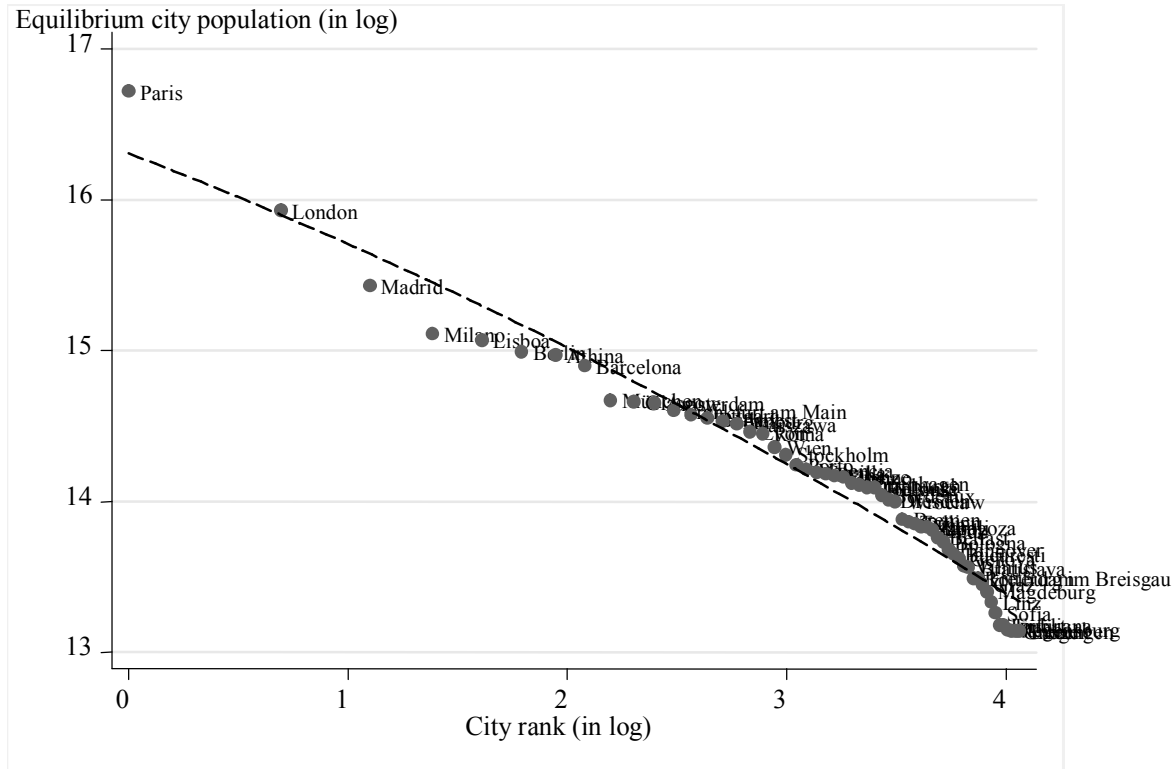
Figure 7 shows these results, by plotting the percentage difference between the log of city population predicted by the model and the log of actual population for each FUA. Different considerations emerge from this Figure. Firstly, the Figure shows a remarkable fit of the model: the range of the percentage difference is between +6% and -6%. Moreover, the Pearson's correlation coefficient between these two variables (not reported in the figure) is equal to 0.92, significant at all conventional levels. All this implies that the model, in line with the  $R^2$ s shown in Tables 2 and 3, is capable of predicting most of the variance in the data. This is further reinforced by the fact that our estimates satisfy Zipf's law for cities, as requested in most recent urban economics literature (see for instance Gabaix, 1999) (Figure 8).

**Figure 7. Predicted urban 'equilibrium' size (in % on actual size).**



Source: authors' calculations.

**Figure 8. Zipf's law for the theoretical model.**



Source: authors' calculations.

Secondly, as all residual measures (like a Total Factor Productivity measure: Syverson, 2011), the distance between the predicted population and the real population represents a measure of our ignorance. For those cities that register a predicted population higher than the real population (the positive values in Figure 7), possible margins of growth exist, thanks to improvement in some efficiency characteristics not being captured by the model. Such characteristics are probably qualitative in nature, such as the quality of urban governance: cities with better long-run strategies may in fact afford, *coeteris paribus*, a larger equilibrium size - a higher predicted population growth in Figure 7. The opposite condition holds for cities that show a real population higher than the predicted one: good urban governance, effective marketing, symbolic effects linked to political and economic power and control might have cumulatively pushed urban size beyond its equilibrium point (Camagni, 2001).

## 8. Conclusions

Since their birth, urban agglomerations have been the loci of innovation, where human capital investment is attracted by higher returns, and, as a famous saying goes, the place where people are truly free.<sup>20</sup> Recent developments in the urban world, however, prompted the emergence of new trends for urban location. Not only does it pay off to accumulate human capital and locate where the returns associated to education are highest, but it becomes also increasingly important to enjoy the more open atmosphere characterizing modern urban agglomerations.

In this paper a model of equilibrium urban size is formulated with the aim to assess the determinants of city size, mentioned in both the neoclassical and non-conventional (more recent) approaches to urban size. This theoretical model is then tested on 59 Functional urban Areas within the EU27. Not just a single 'optimal' city size exists, but many 'equilibrium' sizes according to the presence in each city of specific costs and advantages.

<sup>20</sup> *Stadtluft macht frei*, as predicted by a medieval saying.

The evidence suggests that indeed modern paradigms explain much of current size disparities. While rent, net of the urban benefits it reflects, still represents the single highest cost associated to urban size, cities benefit not only from attracting highly educated professionals, and hosting a rich and diversified market, but also from pure amenities, which are found to be associated with a larger urban size.

Besides, results clearly and consistently show that being connected to an urban network - in this case, a cooperation network in the scientific field - allows cities to achieve a larger equilibrium size. The same role is played by presence of high order functions, even if the empirical validation is less robust.

Empirical results have allowed the identification of city-specific variability: some cities show an actual population which is lower (higher) than the equilibrium city size predicted by the model. Differences can be explained by good or bad governance, thereby suggesting future strategies for more efficient urban planning and sound economic and social 'visions'.

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## Appendix 1. Administrative regions employed in the construction of LUZ.

**Table A1. Administrative regions employed in the construction of LUZ.**

Country	N° of cities with LUZ	Building blocks
AT	All	3 NUTS 3 units (Groups of political “Bezirk”). LUZ of Vienna has 3 units
BE	All 6 Communes	NUTS 5 – delimitation of commuting zones based on 1991 Census
BG	All	7 NUTS 4
CY	1 of 1	NUTS4
CZ	All	5 NUTS 4
DE	28 of 35 (common LUZ for Ruhr)	Groups of NUTS 3 /Kreise
DK	All	4 Amter (NUTS 3). Copenhagen: several units
EE	All	2 NUTS 4
ES	All	Provincias / NUTS 3
FI	All	4 NUTS 5 units which constitute metropolitan areas
FR	27 of 31	Aires Urbaines, statistically defined. Do not exist in the overseas departments
GR	All	9 Nomos (NUTS 3) except outlying islands which belong to Attiki
HU	All	4 NUTS 4; Budapest: agglomeration based on NUTS 5 units
IE	3 of 4	Two NUTS 3 units for Dublin. NUTS 5 used for Cork and Limerick.
IT	All	27 Province NUTS 3

LT	All	3 NUTS 4
LU	1 of 1	Communes NUTS 5
LV	All	2 NUTS 4
MT	1 of 2	NUTS 3 = island
NL	All	10 COROP-regios (NUTS 3), in some cases 2 regions for one LUZ
PL	All	22 NUTS 4; smaller cities: NUTS 5
PT	2 of 8 (the other 6 towns use one concelho each)	Concelhos NUTS 4
RO	All	14 NUTS 5
SE	All	5 NUTS 3 for Stockholm; NUTS 5 units which constitute metropolitan areas for 2 cities; Local Labour Market areas for remaining 2 towns
SI	All	2 NUTS 3
SK	All	14 NUTS 5
UK	20 of 24 (some cities share a common LUZ)	Districts/Unitary Areas (NUTS 4), with one exception that will use NUTS 5 (Lincoln)

Source: EUROSTAT (2004).

## Appendix 2. Land rent data sources.

**Table A2. Land rent sources.**

Country	Source of house prices data	Year
Austria	Global Property Guide ( <a href="http://www.globalpropertyguide.com">www.globalpropertyguide.com</a> )	2006
Belgium	Institut National de Statistique	2006
Bulgaria	National Statistical Institute	2006
Cyprus	Global Property Guide ( <a href="http://www.globalpropertyguide.com">www.globalpropertyguide.com</a> )	2006
Czech Republic	European Property website ( <a href="http://www.europeanproperty.com">www.europeanproperty.com</a> )	2006
Denmark	Urban Audit 2001-2004 data, inflated by 48% (price increase calculated with GPG data)	2006
Estonia	Urban Audit 2001-2004 data, inflated by 61% (price increase calculated with GPG data)	2006
Finland	Urban Audit 2001 data, inflated by 157% (price increase calculated with GPG data)	2006
France	FNAIM house prices statistics	2006
Germany	Urban Audit 2001-2004 data, inflated by price increase calculated with BulwienGesaAG data)	2006
Greece	Various international real estate agencies (e.g. <a href="http://www.mondinion.com/Real_Estate/country/Greece/">http://www.mondinion.com/Real_Estate/country/Greece/</a> )	2006
Hungary	Urban Audit 2001-2004 data, inflated by 20% (price increase calculated with Departement du Logement data)	2006
Italy	Banca dati delle quotazioni immobiliari - Agenzia del territorio ( <a href="http://www.agenziaterritorio.it">http://www.agenziaterritorio.it</a> )	2006
Latvia	Central Statistical Bureau of Latvia	2006
Lithuania	Inreal quarterly report	2006
Malta	Malta's property price index	2006
Netherlands	Urban Audit 2001 data, inflated by 66% (price increase calculated with GPG data)	2006
Poland	Urban Audit 2001 data, inflated by 66% (price increase calculated with GPG data)	2006
Portugal	<a href="http://www.portugalvirtual.pt/real-estate/prices-how-to-finance.php">http://www.portugalvirtual.pt/real-estate/prices-how-to-finance.php</a>	2006
Romania	Urban Audit 2001-2004 data, inflated by 74% (price increase calculated with GPG data)	2006

Slovakia	Urban Audit 2001-2004 data, inflated by 41% (price increase from the house prices index of Central Bank of Slovakia)	2006
Slovenia	Urban Audit 2001-2004 data, inflated by 57% (price increase from the house prices index of Statistics Slovenia)	2006
Spain	Urban Audit 2001-2004 data, inflated by 35% (price increase calculated with GPG data)	2006
Sweden	Värderings Data SA	2006
United Kingdom	Urban Audit 2001-2004 data, inflated by regional housing price inflators as compiled by Nationwide Ltd.	2006

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