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SPATIAL STRUCTURE AND PRODUCTIVITY IN ITALIAN NUTS-3 REGIONS

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Abstract

This work is an investigation of how spatial structure affects labour productivity in Italian provinces. The analysis draws on agglomeration theories, and analyzes whether agglomeration benefits are dependent on the way activities are spatially organized within regions. Urban spatial structures have declined in terms of size, dispersion and polycentricity. Using instrumental variables and spatial econometric techniques, we assess the effects of spatial structure for the 103 Italian NUTS-3 regions. The findings include negative impacts of both polycentricity and dispersion and a positive impact of size.

Key-words: Spatial structure, Polycentricity, Dispersion, Agglomeration externalities, Productivity

JEL classification codes: R11, R12, R14

1 Introduction

Contemporary urban regions have become very complex and heterogeneous in terms of their size and structure. Cities have been expanding,and becoming a regional phenomenon, both from a physical and a functional point of view., As a consequence, the growth of cities has affected the spatial structure of the regions where they are located, at least in terms of *dispersion* and *polycentricity*. On the one hand, activities are either concentrated in (dense) centres or dispersed across the territory. On the other hand, the core of economic activity, traditionally concentrated in city centres, has tended to move towards new (sub) centres, forming polycentric urban regions.

The changes that have characterized metropolitan regions have inspired research on agglomeration economies and optimal spatial structure, especially with reference to the concepts of size, polycentricity and dispersion. In addition, several concepts, such as Polycentric Urban Regions, Edgeless Cities, Mega City Regions, etc., have been introduced in order to identify the boundaries of the "new" spaces where economic processes take place. Using Alonso's concept of "borrowed size", it has been argued that cities and, as a consequence,

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agglomeration economies have regionalised. Accordingly, regional urban systems characterized by strongly interconnected centres are assumed to share the benefits of agglomeration, without incurring the diseconomies that characterize (large) monocentric regions, such as congestion and high land prices.

However, few empirical studies have focused on understanding whether regional spatial structures play any economic role. The existing literature is often characterized by a reductionist approach and tends to use the basic measures of spatial structure, ignoring the functional relationships in centres and focusing only on regional morphological features.

The aim of this paper is to verify whether spatial structure affects productivity in Italian NUTS-3 regions. After reviewing the literature, we quantified regional spatial structures in terms of *size*, *centralization-dispersion* and *polycentricity-monocentricity*. Having identified an aggregated production function including spatial structures such as sources of productivity, a cross-sectional analysis was performed. We controlled for endogeneity and spatial dependence using instrumental variable estimations and spatial econometric techniques.

Our main findings show that larger regions perform better, and that higher centralization and monocentricity lead to higher productivity. This suggests that regionalised agglomeration economies do not replace single-centre agglomeration effects. In other words, physical proximity is still more important than relational proximity at a regional level. At the same time, we also found that the marginal effect of centralization decreases with the size of the region. Thus suggests that there may be effects due to congestion.

The work is organized as follows. Section 2 provides the methodological framework for the role of spatial structure on economic performance and reviews the literature. Section 3 proposes a simple model whose empirical setting is introduced in Section 4 and commented on in Section 5. Section 6 provides the conclusion and suggests further research on this topic.

2 The role of spatial structure for economic performances

2.1 Setting the scene

The process of growth that has characterized the Italian urban system over the last century and a half have considerably affected the shape and structure of cities, both in terms of their physical dimension (*urbs*) and their social dimension (*civitas*). In fact, urban economic development and urban spatial structure are tightly linked (Parr, 1987). The massive structural changes caused by the Industrial Revolution, with both the demographic and urban transition, led to the physical expansion of cities, which increased their role as engines for regional economic growth (Hohenberg and Lees, 1985). Technological progress in transport, which started in the 19th century, allowed for a reduction in space and time constraints for households (Bertolini and Dijst, 2003). However, the distinction between urban and extra-urban environments still held, and cores of cities continued to maintain the role of centres for urban business: “people lived at low densities, but they worked at high densities” (Glaeser and Kahn, 2001, 3). With the advent of the post industrial age, this distinction no longer holds. Further progress on mass transport systems and the increase in private car use made daily activities less dependent on previous urban boundaries (Giuliano and Small, 1996). Jobs followed the residential activity, starting to spread as well (Glaeser et al., 2001). The de-coupling between *urbs* and *civitas* driven by dispersion is now evident in most urban regions.

Another feature of contemporary regional systems is the re-clustering of activities. If in the past the Central Business District (CBD) was a major focal point of the urban economy, as described by the Alonso-Muth-Mills Model, in recent decades activities have tended to re-cluster in new (sub) centres. *Polycentricity* may also be present when existing cities within the same regions become more interconnected. This type of decentralization characterizes (Western) European urban systems, which show higher land constraints and the less availability of open space, compared to American cities. In Europe, cities are traditionally linked to each other, with high relational densities and a physical proximity (Calafati, 2009). Thus, physical growth in cities has appeared more in the form of the coalescence of existing centres rather than the emergence of new cities. On the other hand urban hierarchy, which is shown by the size distribution of cities, appears quite stable (Duranton, 2007).

Regarding the spatial evolution of functional regions, Italy shows patterns that are similar to other countries of Western Europe. In fact, Italy has historically shown high degrees of urbanization (Malanima, 2005), thus core cities are determined and path dependent. In addition, cities tend to be integrated in terms of functions and mutual interactions: this is evident for instance in daily commuting flows.

2.2 A regionalization of agglomeration externalities?

Considering both the US and the European cases, it has been argued that one of the main consequences of the patterns of spatial development that have taken place over the last decades, is that the spatial extent of agglomeration externalities has extended beyond the administrative borders of the city. In other words, cities are becoming a “regional phenomenon” (Meijers and Burger, 2010). If this hypothesis is true, then it is worth understanding whether the extent to which activities are spatially organized within the region – e.g. centralized, dispersed or networked in a polycentric structure – can affect economic performance. To give an example, in centralized regions there is a higher physical proximity between economic agents, and ideas move more quickly than in dispersed regions (Jaffe et al., 1993).

However, the advantages of agglomeration can also be exploited in particular types of decentralized regions, characterized by polycentricity. In fact, they may be shared among a set of medium-sized centres, which “borrow” each other's size in order to achieve the critical mass needed to generate agglomeration economies (Alonso, 1973). This is likely to be the case when considering urbanization economies à la Jacobs, while Marshall-Arrow-Romer externalities are likely to be confined to the urban cores, or at an even lower scale (van Soest et al., 2006).

In order to share the benefits of agglomeration, activities should be not dispersed throughout the region, but concentrated in two or more centres, which must be physically close to one another and in strong relation to each other. In fact, single-node agglomeration economies can be compensated or substituted by the presence of several urban centres that interact with each other through network relations of complementarities or synergies (Camagni and Salone, 1993). These kinds of external economies can be conceptualized as network economies (Boix and Trullén, 2007), which have the specific feature of being shared by nodes that are physically separated but close to each other. Thus, a polycentric structure can, in principle, avoid the diseconomies of congestion that characterize large and monocentric regions. At the same time a polycentric structure has at least some of the advantages of large agglomerations by 'sharing' the agglomeration advantages and the functional specialization of each centre.

These ideas represent a theoretical rationale at the basis of current European and National strategies promoting polycentric development, especially in the European context. In fact, since the European Spatial Development Perspective (ESDP) was published in 1999, the concept of polycentric development ceased to be only analytical and began to assume a normative relevance as a strategic concept to promote both economic, social and sustainability goals (Davoudi, 2003). The ESDP has been followed by other policy statements and has stimulated subsequent research on polycentric spatial structures and social, economic and environmental performances. However, despite the general success of *polycentrism* in the policy agenda, *polycentricity* is still a fuzzy and vague concept and its effectiveness still needs to be corroborated with appropriate empirical research (Meijers, 2008). Policies aiming at polycentric development may thus lack a strong scientific rationale.

2.3 Existing literature

For more than thirty years, spatial structures and economic performance have been recognized as being strictly linked to each other (Parr, 1979; 1987). However, little empirical research, especially on an inter-urban scale, has been carried out in order to link these two dimensions. The gap between research on agglomeration economies and studies on spatial structure, noticed by Parr in 1979, still exists.

The wide literature on agglomeration mainly focuses on the size and density of activities as determinants to foster urban and regional growth (e.g. Ciccone and Hall, 1996; Rosenthal and Strange, 2004), "reaching the general conclusion that productivity rises with city size" (Cervero, 2001, 1652). In addition the literature on networks (Camagni and Salone 1993; Capello, 2000) takes into account the hierarchies in city systems. However, this approach seems to focus on the *links* rather than on the structure of the nodes within regions. Moreover, the network approach does not seem to sufficiently consider physical proximity as a source of synergies.

From an empirical point of view, the works of Lee and Gordon (2007, 2011), Meijers and Burger (2010) and Fallah et al. (2011) explicitly investigated the effects of spatial structure on economic development for U.S. Metropolitan Areas (MAs). Fallah et al. (2011) investigated how the intensity of sprawl of U.S. MAs affects their level of productivity, and found a negative and significant relationship. Lee and Gordon (2007) studied the effects of spatial structure on economic performances, where the latter were measured with employment growth in the period 1990-2000. They found that spatial structure affects growth depending on city size: clustered MAs showed faster employment growth when they are small. However, they did not find any effect of decentralization (monocentricity or polycentricity). The results were confirmed by their further research, which considered net business formation as a proxy for economic performance (Lee and Gordon, 2011).

Meijers and Burger's contribution (2010) was based on Lee and Gordon's work. Again, U.S. MAs were investigated and labour productivity was taken into account as a measure for economic performance in 2000. Their findings showed that dispersion was not harmful for labour productivity and that polycentric MAs were characterized by better performance. However, polycentricity seemed to slow the positive effects of metropolitan size (i.e. large and monocentric areas perform bettered than large and polycentric ones) and was more efficient for smaller MAs.

Contrary to the latter findings, by analysing a cross-section of 47 US MAs, Cervero (2001) found that employment density and urban primacy are positively associated with worker productivity, thus corroborating the hypothesis of agglomeration economies at a metropolitan level. However, metropolitan size had no influence on productivity, similarly to what had been found by Ciccone and Hall (1996).

Regarding polycentricity, few analyses have been carried out to assess its role for economic performance. Of these, Vandermotten et al. (2007) found the positive effects of monocentricity on efficiency in European regions, expressed in GDP per capita. These findings have also been confirmed by Meijers and Sandberg (2008), which, however, used European countries as units of analysis

In all the above-mentioned works, polycentricity is expressed in terms of morphology and measured mainly with rank size distributions. We found no papers where this spatial dimension was dealt with by considering functional relationships between territorial nodes. Our work also aims to contribute in this area.

3 Model

In order to investigate the effect of spatial structure on localised productivity, we start with a very simple model, on the basis of previous works by Ciccone and Hall (1996) and Ciccone (2002).

In our model, we use a Cobb-Douglas production function with constant returns of scale to measure the output of firms:

$$Y=AL^{\alpha}K^{\beta}N^{\gamma}H^{\varphi} \tag{1}$$

where traditional inputs have been included, such as labour (*L*), capital (*K*), land (*N*) and human capital (*H*). Equation (1) can easily be rewritten in an intensive form, by dividing both sides by *L*. Given constant returns to scale in the production function, this transformation yields:

$$y=Ak^{\beta}n^{\gamma}h^{\varphi} \tag{2}$$

with lower case letters indicating per unit of labour factors. *A* represents a firm's environment, hence it is a measure of total factor productivity. The latter, according to Rosenthal and Strange (2004, 2126), allows for the influence of agglomeration. This means that with the hypothesis of regionalizing agglomeration economies, total factor productivity is affected by the spatial structure (size, polycentricity-monocentricity and centralization-dispersion) of regions where firms are located. Hence, total factor productivity is assumed to be a function of spatial structure characteristics and other relevant factors, as in equation (3):

$$A_i = \exp\left[\alpha_0 + \sum_{j=1}^{J}\theta_j X_{ji}\right] \tag{3}$$

where X_{ji} includes spatial structure variables – size, polycentricity and centralization – and other factors such as industrial diversity, sectorial specialization in high-productive activities and other location-specific characteristics (regional dummies). Regarding the variables of spatial structure, size catches the strength of urbanization economies. Centralization is the extent to which activities are located to close each other, thus it tells to what extent they are centralized in one single centre rather than being spread throughout a region. In addition, polycentricity reflects the extent to which a region is characterized by the presence of several connected central nodes. α_0 reflects the remaining part of total factor productivity which is not explained by the variables included.

Substituting (3) in (2) and log-transforming the result yields the following linear equation (4), which is used as the reference equation in the empirical analysis.

$$\ln (y)= \alpha + \beta \ln(k) + \gamma \ln(n) + \varphi \ln(h) + \sum_i \theta_i \ln(x_i) + \varepsilon , \quad (4)$$

where ε is an independent and identically distributed error term.

4. Data and variables

4.1 Quantifying spatial structures

The rationale behind this work is that agglomeration externalities can play a role at a regional level, through a particular configuration of the spatial structure. In order to test whether this idea is supported with empirical evidence, it is necessary to identify and quantify the most important characteristics of spatial structure. In line with the literature in this field (Tsai, 2005; Lee and Gordon, 2007; Meijers and Burger, 2010), spatial structure is conceptually expressed with three main components: size and the two spatial dichotomies related to monocentricity-polycentricity and centralization-decentralization.

Size is easily measurable with a total regional population and accounts for the overall strength of any agglomeration forces at work in a particular area. However, by looking at size alone it is impossible to know the nature of agglomeration and how population, jobs and activities are spatially organized within each region. In this respect, the monocentricity-polycentricity dichotomy leads to a deeper characterization of spatial structure at a metropolitan or regional level. This thus helps us to understand to what extent activities are concentrated in the central urban node or, alternatively, distributed over several urban centres.

Although often conceptualized as a pure morphological concept, polycentricity has a functional dimension that needs to be taken into account when analysing the potential economic implications of different spatial structures. In order to quantitatively characterize this specific feature of spatial structure, it is necessary to adopt an indicator that is able to take into account not only the physical distribution of activities, but also the functional relation that takes place within a region.

Recent works in the literature have contributed to these kinds of measurements. One of the most suitable is the Special Functional Polycentricity index (P_{SF}) proposed by Green (2007: 2084). P_{SF} is based on two fundamental assumptions. The first is that a region can be defined as polycentric if it is characterized by two or more central nodes (Riguelle et al., 2007: 195). The second is that these nodes must be functionally linked to one another, where relationships among nodes are based on functional features such as synergies or complementarities. The P_{SF} index is built using commuting flows between municipalities analysed using network analysis tools. It is obtained following the formula indicated in (1):

$$P_{SF}(N) = (1 - \frac{\sigma_{\partial}}{\sigma_{\partial \max}}) \cdot \Delta \qquad (1)$$

where σ_{∂} is the standard deviation of nodal in-degree within the MA N; $\sigma_{\partial\max}$ is the standard deviation of the nodal in-degree of a 2-node network (n_1, n_2) derived from N where d_{n1} = 0 and d_{n2} = value of the node with the highest value in N; and Δ is the density of the network. Nodal in-degree is the number of links that connect one given municipality with another municipality within the same region. In a network analysis it represents a straightforward and stable measurement of node centrality. Hence, P_{SF} combines the spatial distribution of centralities with the density of the functional relations – measured in terms of commuting flows – that take place within a region (Δ). The P_{SF} index ranges from 0 to 1, where 0 indicates perfect monocentricity and 1 perfect polycentricity.

The third dimension that has been used to characterize regional spatial structure is the centralization-decentralization dichotomy. It is well known that over the last few decades almost all cities in Western countries have decentralized their population and jobs from their core cities into their respective hinterlands (Lee, 2007; Glaeser and Kahn, 2004). However, this process has taken different forms and has occurred with different intensities. While in some cases there has been a shift towards a polycentric spatial structure, in other cases a pattern of generalized dispersion has taken place (Gordon and Richardson, 1996; Lang, 2003). In order to measure the degree of centralization in Italian NUTS-3 regions, a very different indicator proposed by Lee (2007) was used, which is a modified version of an indicator proposed by Wheaton (2004). Lee's measure of centralization can be computed as follows:

$$centr = \left(\sum_{i=1}^{N} P_{i-1} DCBD_i - \sum_{i=1}^{N} P_i DCBD_{i-1} \right) / DCBD^* \qquad (2)$$

where P_i is the cumulative proportion of population in the i-th municipality within a given province; $DCBD_i$ is the distance of the i-th municipality from the central municipality, which for simplicity is called "Central Business District" (CBD); and $DCBD^*$ is the distance of the outermost municipality from CBD and approximates the radius of a region with a hypothesized circular form. All municipalities must be sorted in ascending order by the distance from CBD. This indicator ranges from -1 to 1, where 1 indicates perfect centralization. Compared with the polycentricity index, this measure is focused more on morphology and explicitly considers the physical proximity (distance) between activities located in the region.

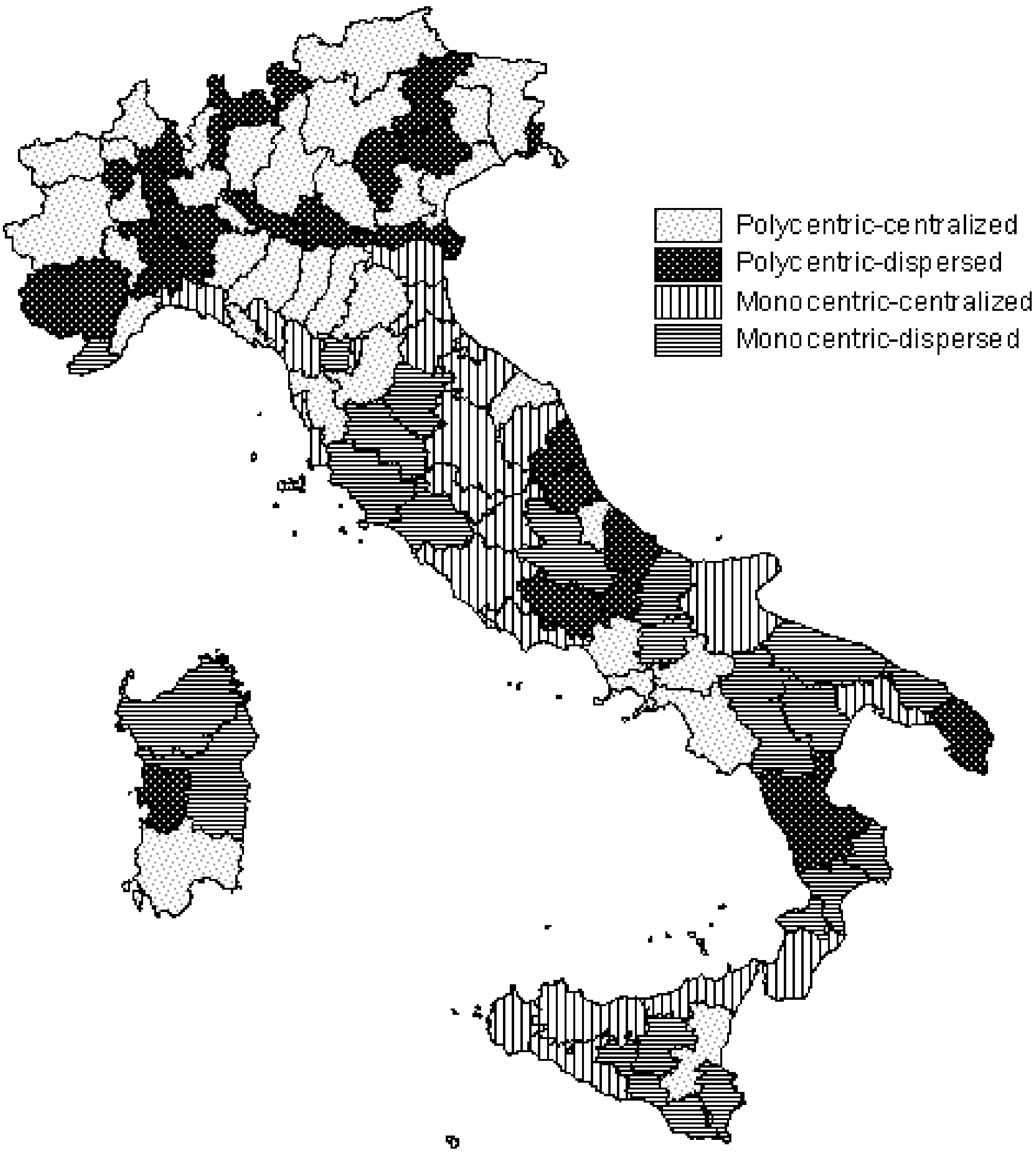
4.2 Dependent and control variables

The other variables that were taken into account regard all the factors and controls that enter the production function specified in Section 3.1, as well as the geographical dummies and instruments that were included in the empirical analysis to achieve consistent estimations. All the variables are summarized in Table 1, together with descriptions and some basic statistics.

The dependent variable is labour productivity per worker, calculated as the ratio between the real GDP and the number of jobs in the private sector, where the data refer to 2001. The variable relative to the capital-labour ratio was computed using Paci and Pusceddu's (2000) estimations of regional fixed capital, which was subsequently attributed to each NUTS-3 region on the basis of employment shares. The land-labour ratio was computed using total regional areas, as reported in the Istat (the Italian National Institute for Statistics) Census of 2001. The variable of education (*graduates*) was computed as the share of graduates over the total number of residents older than 25 in 2001. The sectorial structure of each region was controlled in two ways. First, through an index of productive diversity (*hhi*) – consisting in the inverse of the Herfindahl index at a three-digit level in the private sector. Secondly, the share of employment in the FIRE industries (Finance, Insurance and Real Estate) over total employment in the private sector was included in order to control for the spatial distribution of particularly high-productive sectors.

As far as instrument variables are concerned, variables relative to size and centralization were also computed using 1951 Census data. On the other hand, polycentricity was computed using 1991 data, which represent the first available data on commuting flows. Of the other instrument variables, *accidents* is the number of traffic accidents in 2001, *pivot_job* is the share of jobs in the central municipality over the total number of jobs in 2001, and *rank_size* is the estimated coefficient of a linear equation where the log of resident population in each consolidated municipality is regressed over the log of its rank. This variable is a standard measure of morphological polycentricity and acts as an instrument variable for the polycentricity-monocentricity spatial dimension.

Figure 1 The spatial structure of Italian NUTS-3 regions: a simple taxonomy



Before introducing the estimation strategy that was used to verify the role of spatial structure characteristics on productivity, some basic empirical evidence is worth analysing. Figure 1 highlights the negative correlation of Italian NUTS-3 regions – – between the degree of polycentricity and productivity levels in 2001. (This negative correlation is not particularly strong: the Pearson coefficient is -0.14). Figure 2 shows the clear positive association between the level of centralization of activities and productivity (p=0.34). Finally, there is also a clear and positive correlation between overall regional size and productivity (Fig. 3).

The evidence highlighted in Fig. 1 is consistent with the hypothesis that Italian NUTS-3 regions benefit from agglomeration economies, and that a larger and higher centralization of activities is positive for economic performance. Diseconomies of congestion do not play an important role, considering the relatively small dimensions of the Italian NUTS-3 regions, except from a few metropolitan areas such as Rome, Milan, Naples and Turin. However, the analysis that follows is aimed at verifying whether this hypothesis is empirically founded. All non dummy variables are in log form to allow for a straightforward interpretation of the estimated coefficients in terms of elasticity.

There are several reasons for choosing NUTS-3 regions as units of analysis. First, these regions are administrative units with important policy powers, especially in the field of territorial planning. Hence, focusing on this spatial scale makes a perfect congruence between the object of analysis and the subject of policy. This then enables there to be a more direct and easy transposition of the results in terms of possible policy recommendations. Secondly, the political and administrative powers of Italian NUTS-3 regions are provided for metropolitan areas[1]. The metropolitan area is the most investigated scale in the literature in terms of the regionalization of agglomeration economies. Thirdly, data availability, especially for productivity measurements, means that the best unit of analysis is the NUTS-3 regions.

1 In 1990 Italian law introduced the possibility of setting metropolitan areas as units of analysis, which would take the same power as NUTS-3 regions. At the moment, no metropolitan area has yet been set.

Figure 2 Polycentricity and per worker productivity levels (logs) in Italian NUTS-3 regions, 2001

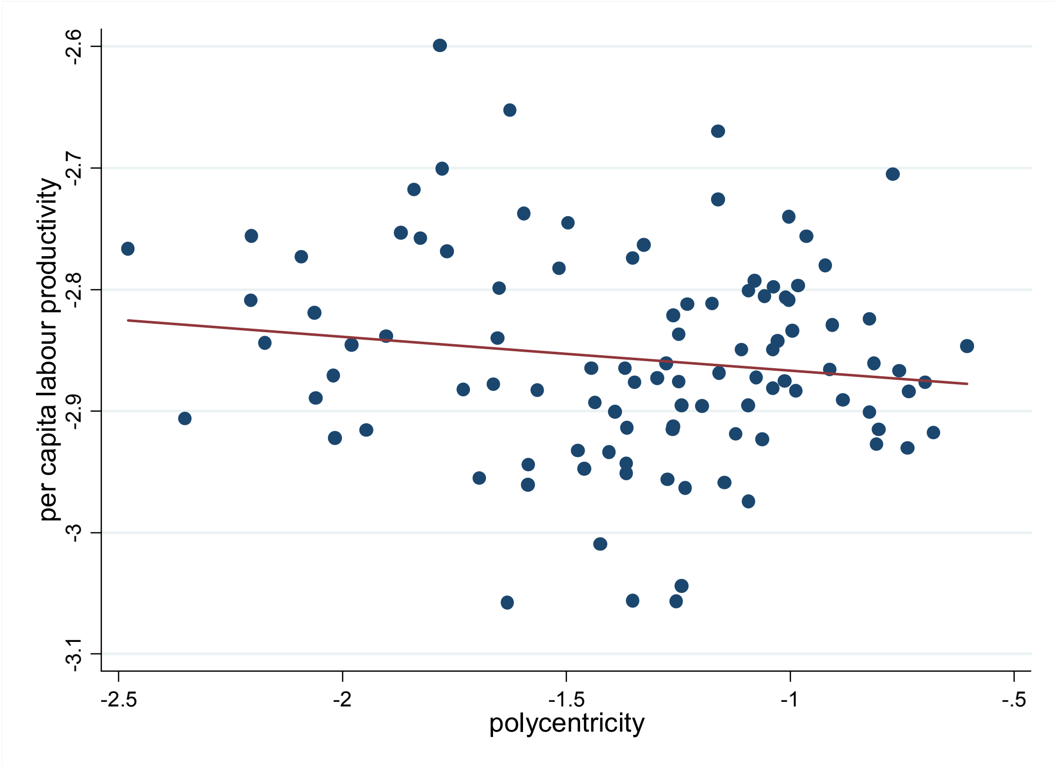


Figure 3 Centralization of the spatial structure and per worker productivity levels (logs) in Italian NUTS-3 regions, 2001

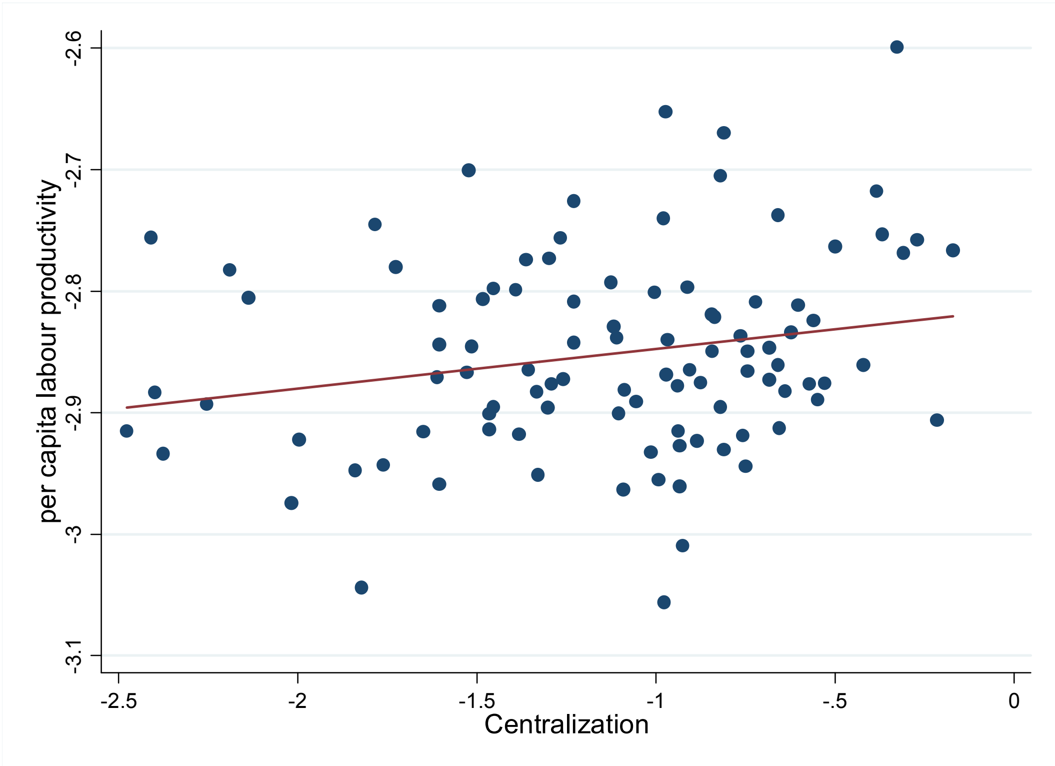


Figure 4 Regional size (total population) and per worker productivity levels (logs) in Italian NUTS-3 regions, 2001

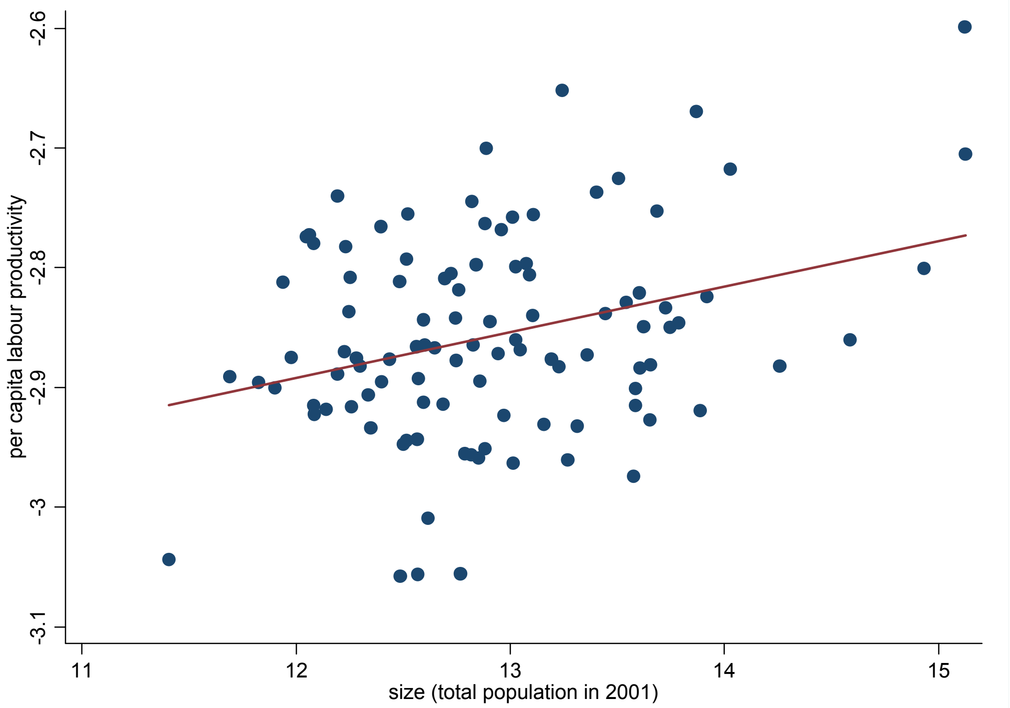


Table 1 List of variables with description, source of data and basic statistics

Variables	Variable description	Data source	Mean	Std.Dev.	Min	Max
lab_productivity (ln)	per capita labour productivity	Istat, 2001	-2.857	0.086	-3.058	-2.599
k_lab_ratio (ln)	kapital - labour ratio	Istat(2001), Paci and Pusceddu (2000)	-0.921	0.250	-1.221	-0.437
land_lab_ratio (ln)	total land area - labour ratio	Istat, 2001	0.942	0.930	-2.010	2.908
graduates (ln)	share of graduates over population older than 25	Istat, 2001	-2.466	0.167	-2.842	-1.878
size (ln)	total resident population	Istat, 2001	12.921	0.708	11.406	15.126
polycentricity (ln)	Green index of polycentricity (Green, 2007)	Istat, 2001	-1.341	0.416	-2.477	-0.605
centralization (ln)	Wheaton index of centralization (Wheaton, 2004)	Istat, 2001	-1.227	0.724	-4.605	-0.171
polyc91 (ln)	Green index of polycentricity for 1991	Istat, 1991	-1.697	0.641	-5.428	-0.750
centraliz51 (ln)	Wheaton index of centralization for 1951	Istat, 1951	2.305	0.023	2.201	2.372
size51 (ln)	total resident population in 1951	Istat, 1951	12.822	0.629	11.453	14.659
accidents (ln)	number of traffic accidents	Istat, 2001	7.412	0.834	5.380	10.360
rank_size (ln)	estimated size-rank coefficients (proxy of polycentricity)	Istat, 2001	0.254	0.214	-0.219	1.020
pivot_job (ln)	share of jobs in the central municipality	Istat, 2001	-1.123	0.397	-2.079	-0.130
hhi (ln)	inverse of the Herfindahl index of sectorial diversity for 2001	Istat, 2001	2.515	0.246	1.796	2.965
fire (ln)	share of employment in finance, insurance and real estate	Istat, 2001	-1.804	0.174	-2.216	-1.113
d_north	dummy variable: 1 value for Northern regions		0.447	0.500	0	1
d_centre	dummy variable: 1 value for Central regions		0.204	0.405	0	1

5 Empirical specification and results

In this section we investigate empirically whether urbanization and (regionalized) agglomeration externalities influence productivity in the Italian NUTS-3 regions. On the basis of the theoretical foundations in Section 3, an econometric model was estimated using different strategies. Table 3 shows the results of these estimations and also provides various diagnostic statistics.

5.1 Dealing with endogeneity

From an econometric point of view, one major issue is the possible endogeneity of spatial structure regressors. This is because conceptually there may be a problem of recursive causality, in the sense that the spatial structure of a region may be, at least to some extent, driven by the economic performance of the region itself (Parr, 1979; Graham et al., 2010). In other words, firms and households may be located in a region, or, more specifically, close to the central municipality because of the advantages of proximity, thus influencing the spatial structure of the whole region. As a matter of fact, although our aim was to test the hypothesis that spatial structure affects productivity, from an empirical point of view, this relationship may work in the other way round, i.e. productivity affects spatial structure. If this is the case, an ordinary least squares (OLS) estimation would not take this endogeneity issue into account and would lead to inconsistent estimates.

In order to correct for the endogeneity of regressors, one possible solution is to use a two-stage least squares (2SLS) estimator, using appropriate instrument variables. Table 2 shows the results of a set of statistical tests to assess the hypothesis of endogeneity, as well as the strength and the validity of the instruments for each of the three variables of spatial structure and for the three variables taken together. For each column in Table 3, hence for each variable of spatial structure and for the set, both OLS and 2SLS regressions were run in order to conduct the tests. In addition, in order to assess the validity of the instruments (Sargan and Basmann tests) at least two instruments for each endogenous variable were included. Both Sargan and Basmann's tests are accepted, so that the null hypothesis that instruments are uncorrelated with the error term cannot be rejected and instruments can be considered as valid (Table 2).

As far as the significance of the instruments is concerned, Anderson's canonical correlation is always significant, as is the Cragg-Donald *F*-test, hence it is possible to reject the null hypothesis of weak instruments. In addition, by looking at Shea partial R^2 , the significance of the instruments is confirmed, given the relatively high levels of all the correlation coefficients. Regarding the exogeneity test of the spatial structure variables, both Wu-Hausman and Durbin tests allow the null hypothesis, under which regressors are exogenous, to be accepted. As a consequence, OLS estimates are consistent. These results were confirmed for all the spatial structure variables, considered both separately and jointly (Table 2). The reasons why these variables are exogenous are in the viscous nature of spatial structures. The organization of activities in space only changes in the long run, and cannot be affected easily by short term economic dynamics (Lee and Gordon, 2007). In addition, the Italian – and maybe European – regional spatial structure is mainly the result of the changing relations and equilibriums between existing urban nodes. The spatial evolution of these nodes, in turn, may have been affected by territorial coalescence, which occurs in the long run (Calafati, 2009).

Table 2 First stage results of the two-stage least-squares (Model 2) regressions on per worker labour productivity

	Size		Polycentricity		Centralization		All	
Instruments								
	population in 1951; car accidents in 2000		polycentricity in 1991; rank-size coefficients in 2001		centralization in 1951; share of jobs located in central municipality		all previous instruments	
Relevance								
Anderson canonical correlation	95.25	***	83.38	***	49.51	***	47.74	***
CD F-test	558.96	***	193.35	***	42.12	***	12.82	***
Critical value CD (10% relative bias)	19.93		19.93		19.93		7.77	
Shea partial R^2								
Size	0.925						0.901	
Polycentricity			0.810				0.760	
Centralization					0.481		0.477	
Validity								
Sargan statistic	0.207		0.198		0.098		0.312	
Basmann statistic	0.183		0.175		0.087		0.270	
Exogeneity								
Wu-Hausman *F*-test	2.255		0.004		0.970		1.132	
Durbin	2.490		0.004		1.086		3.787	
Observations	103		103		103		103	
Regressors	11		11		11		11	
Instrumentes	12		12		12		14	
Excluded instruments	2		2		2		6	

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

5.2 Dealing with spatial autocorrelation of residuals

The possible bias caused by the spatial autocorrelation of residuals represents another problem in the empirical analysis. This happens because the units of analysis are territorial entities, close to one another, which could show similar behaviour on the basis of geographical proximity. If regression residuals are spatially auto-correlated, then OLS estimates are biased. More specifically, bias could affect the consistency or the efficiency of the estimates on the basis of the spatial model that generates data. Spatial autocorrelation of residuals can be due to a spatial dependence mechanism or to an unobserved spatial heterogeneity of coefficients. In other words, before interpreting the residuals' spatial autocorrelations in terms of spatial dependence (e.g. spillovers of productivity between regions, or spatial diffusion of economic shocks from one given region to a neighbouring region) any potential spatial heterogeneity needs to be removed from the model. For this reason, two regional dummies (*d_north*, *d_centre*) were included in the model, given that Italian economic development is strongly differentiated between the north, south and centre of the country. Even including the two macro-regional dummies, Moran's *I* statistic does not allow for the hypothesis that residuals are not spatially correlated for both OLS and 2SLS estimations (Models 1-2, Tab. 3). In order to deal with this problem and to get consistent estimates, a spatial lag model was estimated using instrumental variables (S2SLS), after looking at the results of a robust LM test of spatial autocorrelation. The spatial lag model includes the spatial lag[2] of the dependent variable, which was instrumented with the spatial lag of the regressors, as suggested by Kelejian and Prucha (1998). The choice of a S2SLS is also consistent with spatial auto-correlated shocks and can at the same time deal with the potential endogeneity of spatial structure variables.

5.3 Interpreting results

Results of the empirical analysis carried out on the basis of the theoretical model discussed in Section 3 are presented in Table 3. For all the estimated models, White's standard errors were used. OLS estimations are robust for using different estimation strategies that were adopted in order to deal with endogeneity of regressors or spatial autocorrelation of residuals. Signs of estimated coefficients do not change and magnitudes present only small differences. Coefficients relative to all the traditional regressors show the expected sign. In fact, the control for capital-labour ratio is positive, as well as the controls relative to land-labour ratio and to the share of graduates. The two latter variables, however, are not statistically different from zero, which is consistent with the results obtained by Meijers and Burger (2010). The non

[2] In order to compute spatial lags, different weight matrixes were used, based on distance thresholds, contiguity and *k*-nearest neighbourhood. Results are robust for using of all kinds of spatial weights. Tables and tests are reported here using four-nearest neighbours matrixes.

significant role of high-level education for economic performance is not a new finding in the Italian case (Cirilli and Veneri, 2011; Pietrobelli, 1998). These results have different explanations, from the sectorial composition of the Italian economic system to the weakness of university graduates as a measure of human capital, and similar results have also been found for other countries (Cheshire and Magrini, 2006).

Regional dummies are also statistically significant and show the expected sign, since the reference region – the south of Italy – is thought to be the economically weakest region in the country, followed by central Italy. Regarding the spatial lag of the dependent variable (*Wy* in Model 3), it proved to be positive and significant, with a very high elasticity (35.5%). This means that if a region has a high level of productivity, its neighbours strongly benefit in their productivity levels thanks to physical proximity. Regarding sectorial specialization, results show that more diversified economies perform better, while the specialization on the FIRE industries turns out to be positive, as expected, but statistically not significant.

Turning to the spatial structure variables, which is the main focus of this work, results show that all the three dimensions of spatial structure – size, polycentricity and centralization – significantly affect the productivity levels of the Italian NUTS-3 regions. Regional size accounts for the intensity of urbanization externalities and, in agreement with most of the literature, it has a positive and significant impact on labour productivity. The elasticity of size with respect to productivity is 3.6% (Model 3), as confirmed by Rosenthal and Strange (2004), who reported an elasticity range from 3% to 8%.

As far as centralization is concerned, results show that more centralized regions are associated with a higher productivity. By doubling the centralization of activities, labour productivity increases by 2.7%. This confirms the hypothesis that a more concentrated pattern in the spatial distribution of activities leads to higher agglomeration economies and, as a consequence, to higher economic performance.

The degree of regional polycentricity was negatively associated with productivity levels, which is consistent with Vandermotten et al. (2007). This result does not confirm the hypothesis that, at least with regard to NUTS-3, agglomeration economies have regionalized. Hence, the mechanism of "borrowing size" with which polycentric structures can take the place of a single large agglomeration (monocentric structure) does not occur within regions. A negative association between polycentricity and economic performances has also been found by Lee and Gordon (2007), but without a strong statistical significance.

Table 3 Estimation results. Dependent variable: *lab_productivity*. Robust standard errors are reported in brackets.

	Model 1: OLS		Model 2: 2SLS		Model 3: S2SLS	
intercept	-3.015	(0.273)***	-3.093	(0.267)***	-1.989	(0.685)***
k_lab_ratio	0.195	(0.043)***	0.194	(0.040)***	0.120	(0.056)**
land_lab_ratio	0.005	(0.010)	0.007	(0.009)	0.005	(0.009)
graduates	0.035	(0.064)	0.031	(0.061)	0.038	(0.057)
d_north	0.118	(0.029)***	0.119	(0.029)***	0.083	(0.036)**
d_centre	0.050	(0.023)**	0.051	(0.022)**	0.033	(0.025)
hhi	-0.062	(0.041)	-0.067	(0.039)*	-0.069	(0.037)*
fire	0.043	(0.071)	0.025	(0.066)	0.038	(0.060)
size	0.043	(0.016)***	0.047	(0.016)***	0.041	(0.015)***
polycentricity	-0.043	(0.021)**	-0.042	(0.022)*	-0.036	(0.022)*
centralization	0.019	(0.009)**	0.028	(0.012)**	0.027	(0.011)**
Wy					0.355	(0.198)*
N. observation	103		103		103.000	
Squared R	0.500		0.495		0.567	
F test	10.61	***	115.19	***	149.32	***
Breusch-Pagan test	0.03		6.89		9.68	
Ramsey RESET test	0.37		0.03		0.29	
Mean VIF	2.57		2.73		3.58	
Observed Moran's *I*	0.151	***	0.142	***	-0.037	

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

As argued by Lee and Gordon (2007), the growth effects of spatial structure can be dependent on metropolitan size. The final part of our analysis investigates the role of size, polycentricity and centralization for small and large regions. Table 4 reports signs and significance of coefficients estimated using OLS with robust standard errors, where regions have been divided into two groups according to their size: small regions are those with a population less than 350,000 inhabitants in 2001, while large regions are those with a population higher than 350,000.

Given the limited number of observations in each group and the possible limitations in the reliability of the estimations, it is worth focusing on the coefficient signs and on their statistical significance. The results in Table 4 show that, although there is a decrease in most of the significance of the coefficients , the signs of spatial structure variables are always consistent with those found using the whole set of statistical units (Table 3). The statistical significance of the total population coefficient is higher for the group of large regions. This suggests that the overall strength of agglomeration forces has a significant effect on small and medium-sized regions, while the same effect decreases in particularly large regions, where agglomeration diseconomies may arise.

Table 4 Estimation results. Dependent variable: *lab_productivity*. Estimations for regions of different size classes. Robust standard errors are reported in brackets.

	Small regions		Large regions	
intercept	-3.960	(0.548)***	-2.137	(0.366)***
k_lab_ratio	0.121	(0.066)*	0.307	(0.064)***
land_lab_ratio	0.015	(0.013)	-0.019	(0.015)
graduates	-.0810	(0.085)	0.094	(0.077)
d_north	0.0693	(0.044)	0.150	(0.037)***
d_centre	-0.002	(0.032)	0.076	(0.029)**
hhi	-0.005	(0.052)	-0.118	(0.061)*
fire	0.082	(0.061)	0.056	(0.065)
size	0.080	(0.036)*	0.002	(0.025)
polycentricity	-0.031	(0.024)	-0.031	(0.031)
centralization	0.043	(0.023)*	0.008	(0.007)
N. observation	47		56	
Squared R	0.408		0.680	

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

6 Concluding Remarks

The aim of this work was to contribute to the debate on the effects of spatial structure on the economic performances of regions. Particular focus was on the measurement of spatial structure characteristics, since size and density, taken alone, cannot detail exactly how regions are spatially organized. From the empirical analysis it emerged that spatial structure does play a role in explaining the differences in the levels of productivity.

Four key results were found. Firstly, productivity increases with size, hence confirming the hypothesis that urbanization externalities have a positive and significant effect on labour productivity, and the elasticity is consistent with what has been already found in the literature.

Secondly, the extent to which activities are centralized in the main urban node has a positive and significant impact on productivity. This means that pure physical proximity is important for economic performance, since it is directly related to the generation of agglomeration externalities. Hence, dispersed regions perform worse than compact and centralized regions, highlighting, from a policy perspective, a possible negative economic effect of sprawl.

Thirdly, the degree of polycentricity does not have a positive impact on economic performances. This means that, at least in the sample of Italian NUTS-3 regions considered in this analysis, relational proximity between different centres cannot be a substitute for physical proximity in monocentric regions. Hence, despite the fact that cities and metropolitan areas are now a regional phenomenon, monocentric regions are still stronger in terms of agglomeration externalities.

Finally, the effect of the overall strength of agglomeration forces seems to change on the basis of the size of the regions that were included in the analysis. In fact, size always has a positive impact on productivity. However the magnitude and the significance of the related coefficient is higher for small regions and then decreases for larger regions. The productivity of small-sized regions has previously been thought to be positively affected by polycentric structures, in order to compensate for a smaller size, but this effect was not empirically verified in our study.

Therefore, an optimal spatial structure may not be easily identifiable, since several efficient structures can exist on the basis of the size and on other relevant characteristics of the regions. For example, sectorial composition may play an important role in understanding which spatial structures are more efficient. In fact, although sectorial composition was considered in this analysis, a more thorough study by sector might be useful, since some sectors may only benefit from physical proximity while others may take advantage of relational and functional relations at a regional level. These issues represent promising questions for further research on this topic.

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