THE DETERMINANTS OF LAND USE IN ITALY FROM A SPATIAL PERSPECTIVE: A RE-INTERPRETATION AT THE TIME OF COVID-19

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1. Introduction

Since ancient times, mankind has radically transformed natural soil into artificial areas, exposing sustainability at risk due to the severe implications for the environment, the economy and society at large (Bajocco *et al.*, 2018). This irreversible loss reduces the ability of soils to provide support for the biotic component of the ecosystem and to ensure biodiversity and social enjoyment (Narducci *et al.*, 2019).

Only recently, the need for a systematic understanding of the resulting social and environmental problems has emerged as a prerequisite for designing sustainable policies to reverse current trends in land degradation (European Environmental Agency, 2017). The UN Sustainable Development Goals (SDGs) include strengthening inclusive urbanisation and promoting integrated management solutions for long-term sustainable land use by 2030.

However, due to the lack of coordinated land management background, many countries may not be able to achieve sustainable development objectives without changing their current policy frameworks and land-use practices (Wubie *et al.*, 2021). Moreover, given the pervasiveness of the impact of the Covid-19 pandemic on the different dimensions of sustainable development, urban planning programs and local development policies are likely to be rescheduled. In this respect, the question arises whether the Covid-19 pandemic will be a stimulus to change the current development model in the direction suggested by the SDGs, or whether the policies aimed at tackling the resulting economic damage will overshadow the environmental aspects.

Based on the above, this work aims to provide a deep understanding of the territorial factors that best quantitatively describe land use in Italy from a spatial perspective, investigating spillover effects both in the patterns of land use and in their socio-economic and institutional determinants (Mellino and Ulgiati, 2015; Irwin and Bockstael, 2002). Moreover, in an attempt to give useful insights for policymakers in the design of sustainable land management strategies, this work provides a reinterpretation of the results of spatial econometric models in light of the recent evolutions due to the Covid-19 pandemic.

The remainder of the work is organised as follows. Sections 2 and 3 illustrate methods and data, respectively. Section 4 shows the main results. Section 5 discusses some policy implications and concludes.

2. Method

In a preliminary step, spatial measures are used to assess spatial autocorrelation in land use levels in Italy. Having defined the spatial weight matrix (W), Moran' *I* allows us to evaluate the *global* spatial autocorrelation, i.e. how similar are the land use levels between neighbouring municipalities. Moran's *I* only offers averages in spatial proximity measurement that can hide interesting micro-concentrations of spatial dependence in the phenomenon being analysed. To detect the presence of significant clusters, we also perform *local* Moran's *I*. The local indicators of spatial autocorrelation (LISA) identify 'hot' (high-high) and 'cold' (low-low) spots where municipalities with similar land use levels are adjacent.

Subsequently, in the framework of spatial econometric models, we perform the Spatial Durbin Model (SDM), which includes the spatial lags of the exogenous variables as well as the spatial lags of the endogenous variable (LeSage and Pace, 2009). The SDM provides unbiased coefficient estimates even in the presence of spatial error dependence (Elhorst, 2010). Formally:

$$y = \rho Wy + \alpha \iota_N + X\beta + WX\theta + \varepsilon \qquad \text{with} \qquad \varepsilon \sim N(0_{nx1}, \sigma^2 I_n) \tag{1}$$

where:

- y: dependent variable given by land use rates (LURs, hereafter) observed on all Italian municipalities;
- X: matrix of own-municipality characteristics;
- β: vector of parameters associated with the set of covariates X;
- α: intercept (i_N is the vector of ones);
- W: spatial weight matrix;
- ρ: scalar for the endogenous interaction effects (Wy) known as spatial autoregressive;
- θ: vector of the parameters for the exogenous interaction effects (WX);
- ε: vector of independently and identically distributed error terms with zero mean and constant variance.

The change in a covariate in a given municipality *directly* affects the dependent variable in that municipality and *indirectly* affects the dependent variable (spillover effects) in all other municipalities. Both direct (2) and indirect (3) effects of a

particular covariate also depend on the coefficient θ_k of the spatially lagged value of that variable (Elhorst, 2010). Formally:

$$Diagonal\ elements\ of \quad (I - \rho W)^{-1}[\beta_k + W\theta_k] \tag{2}$$

$$Off - diagonal\ elements\ of \quad (I - \rho W)^{-1}[\beta_k + W\theta_k] \tag{3}$$

3. Data and variables

The analysis is carried out at the municipal level (*n*= 7,998 municipalities). This choice is justified in light of the national legislation that recognises the municipal authority, regardless of its size, as the main decision maker of territorial planning strategies. In addition, municipal data ensure very granular spatial resolution, a key advantage when using spatial econometrics.

According to the official definition (ISPRA-SNPA, 2018), LUR is expressed as the percentage value of existing land actually used for urban purposes (i.e. residential, industrial and commercial) on the total municipal area, net of water bodies. Land use data for 2016 are from ISPRA (Italian Institute for Environmental Protection and Research)[1].

Italy is an interesting case study both for the intense land use compared to other European countries (it ranks 5th in Europe) and for the high levels of heterogeneity across regions (European Environmental Agency, 2017). Five out of eight Italian regions with the highest land use rates are in the centre-north (Lombardy, Veneto, Emilia Romagna, Friuli-Venezia Giulia, Latium, Liguria), two in the South (Campania, Apulia).

The explanatory variables (2016), which concern four macro-areas (i.e. geomorphological, socio-demographic, economic, and institutional characteristics), are taken from SIEPI (Italian Society of Economics and Industrial Policy) and Istat (Italian Institute of Statistics)[2].

Regarding the geomorphological characteristics, we test the *overall surface* and the *altitude*, which are supposed to influence the operational complexity of land use activities. The overall surface is the total territorial area (land and water area) within the municipal boundaries (km^2) and allows controlling for the size heterogeneity of the municipalities. In line with studies demonstrating the existence of structural differences in the behaviour between large and small municipalities (Van Oosten *et*

[1] https://www.isprambiente.gov.it/it/attivita/suolo-e-territorio/il-consumo-di-suolo/i-dati-sul-consumo-di-suolo.

[2] https://www.istat.it/it/archivio/156224; http://asc.istat.it/ASC/asc.html.

al., 2018; Guastella *et al.*, 2017), the overall surface can help explain their different efficiency in land use management. Altitude is the elevation above mean sea level (meters) which inevitably affects land surface physiognomy and, therefore, the suitability of a place for urban use (Huang *et al.*, 2019).

The set of demographic variables concerns the size and composition of the population and households: *population density* (ratio between the total population and the total area of the municipality), *housing per capita* (ratio between the total number of houses and population), and *metropolitan area* (dummy variable: 1 if the municipality belongs to a metropolitan area and 0 otherwise)[3]. In densely populated areas, large-scale land development is usually required to meet the production and lifestyle needs (Pagliacci, 2019; Shu *et al.*, 2018; Culas, 2007). The house is often conceived as a primary asset and one of the main safe-haven investments, although the increase in housing demand does not necessarily translate into greater densification of urban centers (Guastella *et al.*, 2017; Broitman and Koomen, 2015). Metropolitan areas may play a key role in land use process, implying a revised land management and sustainable urban development (European Committee of the Regions, 2019; Mazzocchi *et al.*, 2013).

Moving on to the socio-economic dimension, we test the following variables: *education rate* (rate of people with at least the upper-secondary education), *employment rate* (share of employed people aged 16-64 out of the working-age population), *GDP per capita*, and *enterprises per capita* (total number of enterprises out of the total population). General knowledge and specific skills on environmental issues are generally acquired through formal education, better-educated people may be more aware of the harms resulting from over-exploitation of natural resources (Handavu *et al.*, 2019). Municipalities with high levels of economic activity are likely to exert more pressure on the soil due to the greater propensity of companies to invest in land for commercial and industrial activities (Shu *et al.*, 2018; Meyfroidt *et al.*, 2013; Culas, 2007).

Governance and the quality of institutions can be crucial in land use management (Barbier and Tesfaw, 2015; Galinato and Galinato, 2013). The quality of institutions is proxied by the *Institutional Quality Index* (*IQ*I), which considers five domains of the quality of local governments (corruption, government effectiveness, regulatory quality, rule of law, voice and accountability). IQI ranges between 0 and 1; the closer the IQI to 1, the higher the quality of the local institution (Nifo and Vecchione, 2014).

[3] In Italy there are 14 metropolitan areas (Rome, Milan, Naples, Turin, Bari, Florence, Bologna, Genoa, Venice, Reggio Calabria, Palermo, Catania, Messina, Cagliari).

4. Main results

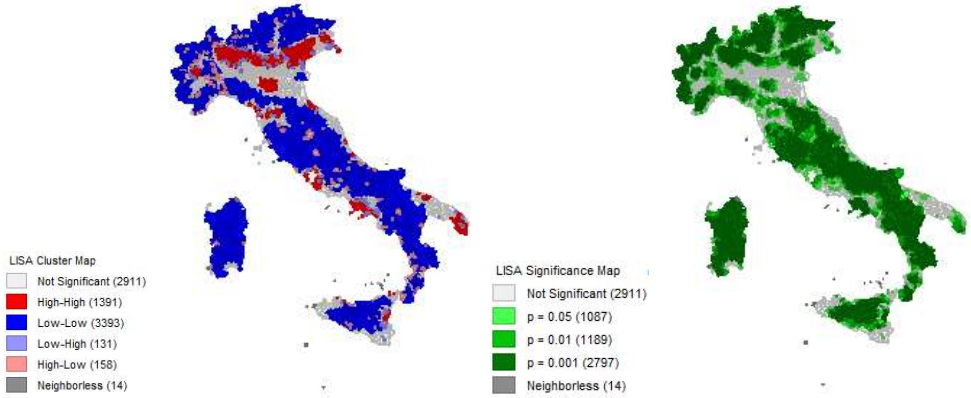
In this section, we first address the global and local spatial correlation in land use levels (4.1) and then discuss the results of the Spatial Durbin Model (4.2).

4.1 Global vs. local spatial correlation

To measure the intensity of the relationships in LURs among municipalities, we used a second order binary contiguity matrix (W) that also includes the first order neighbours. Therefore, two municipalities are adjacent (w_{ij} = 1) if they share an administrative boundary of non-zero length or have borders that touch the first-order neighbours. W is row standardised.

LURs are strongly spatially correlated (global Moran's *I* is 0.684). This means that land use in a municipality directly affects that of neighbouring municipalities. Figure 1 shows the LISA cluster map for LURs and the associated significance map. The 'high-high' cluster of municipalities (hot-spots, red) can be identified in specific areas of Italy – mainly in the North, in the metropolitan area of Naples (Campania) and in the province of Lecce (Apulia) – while the 'low-low' cluster of municipalities (cold-spots, blue) involves the rest of the country.

Figure 1 – *LISA cluster map (a), LISA significance map (b).*



4.2. Spatial Durbin Model results

The choice of SDM is statistically supported by the LM-lag test (LMρ=2,225.9) and its robust version (RLMρ=317.5) (Anselin, 1988; Anselin *et al.*, 1996). Both tests provide significant evidence of the autoregressive term (p-value<2.2e-16) due to the presence of spatial autocorrelation in LURs. The LR test ($\theta + \rho\beta \neq 0$) also detected significant spatial autocorrelation in the covariates (LR: 2,119.7, p-value=2.2e-16).

Table 1 shows the results of the SDM estimation using the spatial weight matrix already illustrated. Table 2 shows the direct, indirect and total effects for each explanatory variable.

Table 1 – *Spatial Durbin Model (SDM): estimation results.*

Variable	Coefficient	St. error
Intercept	0.1894	(.1841)
Geomorphological variables: Elevation above sea	-0.0001***	(.00001)
Demographic variables: Population density	0.5392***	(.0042)
Housing per capita	0.1507***	(.0103)
Metropolitan area	-0.0734***	(.0182)
Socio-demographic variables: Employment rate	0.1326***	(.0334)
GDP per capita	0.1387***	(.0209)
Enterprises p er capita	0.101***	(.0094)
Institutional variables: IQI	-0.1701***	(.0654)
Spatial lag variables: W* Elevation above sea	-0.000001	(.00001)
W*Population density	-0.437***	(.0091)
W*Housing per capita	-0.1574***	(.0168)
W*Metropolitan area	0.0476**	(.0211)
W*Employment rate	-0.1129**	(.05)
W*GDP per capita	-0.1157***	(.0212)
W*Enterprises per capita	0.0637***	(.0208)
W*IQI	0.1768**	(.0717)
ρ	0.8138***	(.0118)
Log likelihood	125.3751	
AIC	-212.75	

Second order binary contiguity matrix (including the first order neighbours), row standardised
**Significant at 10%; **Significant at 5%; ***Significant at 1%*

Table 2 – *Spatial Durbin Model (SDM): direct, indirect and total effects*.

Direct effects	
Elevation above sea	-0.0001***
Population density	0.5394***
Housing per capita	0.1470***
Metropolitan area	-0.0746***
Employment rate	0.1321***
GDP per capita	0.1384***
Enterprises per capita	0.103***
IQI	-0.166***
Indirect effects	
Elevation above sea	-0.0004***
Population density	0.0087
Housing per capita	-0.1828***
Metropolitan area	-0.0632
Employment rate	-0.0266
GDP per capita	-0.0151
Enterprises per capita	0.0969
IQI	0.2022
Total effects	
Elevation above sea	-0.0005***
Population density	0.5481***
Housing per capita	-0.0358
Metropolitan area	-0.1379**
Employment rate	0.1055
GDP per capita	0.1233
Enterprises per capita	0.1999**
IQI	0.0361

Second order binary contiguity matrix (including the first order neighbours), row standardised
**Significant at 10%; **Significant at 5%; ***Significant at 1%*

Overall, the results demonstrate the crucial role of the demographic, socio-economic and institutional characteristics in determining land use levels. As expected, the spatial autoregressive term (ρ) is highly significant and positive, showing the presence of spatial effects. This means that interactions between municipalities play a key role in sketching the land use profile in Italy and that local land use patterns are mutually dependent on those of neighbouring municipalities.

First, both direct and indirect effects show that land use levels decrease with increasing altimetry, which usually makes the territory more morphologically adverse and impairs people's ability to use land. Second, higher demographic pressure and more intense economic development lead to greater land use, in line with the strand of literature that recognises demographic and economic growth as some of the main

determinants of land use (Salvati *et al.*, 2018). It is worth noting that housing per capita acts in the opposite direction if coming from neighbouring areas. Third, the belonging of a municipality to a metropolitan area decreases land use. As an effective intermediate level between the region and the municipalities, metropolitan areas appear to be more integrated internally, fostering cooperation between municipalities to improve the positive effects of agglomeration advantages (ISPRA, 2017). Fourth, the direct effects of the quality of local institutions on land use levels are significantly negative, indicating that better institutions imply a tighter control of the territory and better enforcement of public policies aimed at virtuous management of public affairs and sustainable forward-looking behaviours.

5. Discussion and conclusion

The results suggest that: *i*) monitoring land use is the prerequisite for preserving the environment and ecosystem services throughout the country; *ii*) institutional cooperation, skill- and responsibility-sharing between municipalities should be promoted to reduce administrative fragmentation and develop holistic land use management; *iii*) the strengthening of the qualitative characteristics of local institutions can help narrow regional divides and better manage land use projects.

Such a high spatial resolution analysis is crucial when investigating land use, as it highlights the actual local characteristics that planners cannot ignore in managing the future of sustainable cities, especially in current times characterised by coexistence with the dreadful threat of Covid-19. As suggested by ASVIS (Italian Agency for Sustainable Development), given the key role of sustainable land use in attaining many SDGs, newly designed policies could help mitigate the inevitable slowdowns in their achievement caused by the pandemic. In other words, anti-pandemic policies can benefit from knowledge of how demographic and socio-economic characteristics impact the built environment. In recent months, for example, concerns have been raised about population and housing density, which are supposed to act as risk factors in the spread of Covid-19 (Cordes and Castro, 2020). Since many studies have shown associations between these characteristics and spread of the virus (see Khavarian-Garmsir *et al.*, 2021 for a review), it is inevitable that new land-use planning policies will have to deal with social distancing, which requires the design of new spaces or, at least, the re-organisation of existing ones to avoid overcrowding. In this field, to ensure healthy and more sustainable urban development, planners could support recent trends that see people moving to the suburbs or further afield due to concerns about the risks of living in high-density residential settlements and overcrowded urban areas. This would lead to a potential reduction in housing demand in highly-density municipalities (Liu and Su, 2021), while continuing to preserve rural areas.

The role of metropolitan areas should also be rethought in light of their usually higher infection and mortality rates due to greater connectivity and social contacts. However, it should also be considered that, in the more densely populated and economically developed municipalities, the risk of a faster spread of Covid-19 is usually offset by better access to healthcare facilities and the greater availability of infrastructures and services. As a result, given the crucial role that metropolitan areas play in effective land management, they safety can be preserved by simple rethinking crowding (i.e. through the relocation or decentralisation of industrial areas and activities). Rethinking residential and productive settlements – for example through the recovery of degraded land or the repurpose of those already occupied, the development of green infrastructures and the re-naturalisation of areas that could return to providing ecosystem services – would represent a rational and sustainable way of using the territory. This can help mitigate environmental degradation while safeguarding the health of citizens.

However, the difficulty of predicting the future scenario will likely require a learning-by-doing period in land use policies as well. The future development of the territories should be based on a neighbourhood-oriented plan with periodic adjustments in the awareness that any measures for sustainable land use are effective to the extent that local administrators know the dramatic consequences of a disproportionate use, regardless of the health emergency.

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SUMMARY

The determinants of land use in Italy from a spatial perspective: a re-interpretation at the time of Covid-19

Since the post-Second World War period, territorial development in Italy has been characterised by unsustainable settlement patterns, including the unplanned and wildfire growth of urban systems and the propensity to overbuilding. Systematic knowledge of the key aspects of land use patterns is the basis for planning sustainable land development. Furthermore, the outbreak of the COVID-19 pandemic has accentuated the need to re-address land management to ensure public safety and protection. By using the Spatial Durbin Model (SDM), this work aims to: *i*) analyse the determinants that best quantitatively describe land use patterns in Italian municipalities; *ii*) provide a re-interpretation of the main results in light of the territorial re-planned process required by the Covid-19 pandemic. The results suggest that monitoring land use and strengthening quality and cooperation between local institutions are needed to preserve the environment and ecosystem services that underlie more sustainable land use planning.

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