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METHODS, TOOLS AND BEST PRACTICES

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The cover image is a train passes a rail road crossing that is surrounded by flooding caused by rain and melting snow in Nidderau near Frankfurt, Germany, Wednesday, Feb. 3, 2021. (AP Photo/Michael Probst)

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Territorial disparities in Tuscan industrial assets: a model to assess agglomeration and exposure patterns

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Abstract
Industrial agglomerates are considered *drivers* of urban development. This reiterative process of industrial growth, nevertheless, tends to increase regional territorial disparities, an asymmetrical development pattern that can lead to productive spaces' underuse or abandonment. Although numerous economics studies about industrial distribution and territorial disparities were so far conceived, those are based on dated spatial methodologies. These consider space as an abstract background, hence, leaving unexplored several spatial relations between production, infrastructural networks and industrial agglomerates organization. Novel models ought to consider real attributes of space, being crucial to economic recovery in times of territorial constrains; with this in consideration, the paper objective is to construct and discuss a spatial-economic model tailored to assess territorial disparities in industrial agglomerates distribution and the condition here defined as *territorial exposure*. *Exposure,* represented by a composite spatial index, denotes disparities in territorial endowments, identified as factors of sensitivity or support to firms placed within industrial agglomerates, spatial conditions that can affect their capabilities to react to periods of economic recession and their post-crisis recovery. The model analyses Tuscany Region's industrial structure and depicts territorial disparities in a GIS-based environment. The spatial knowledge produced can aid regional initiatives for economic recovery directed to Tuscan industries.

Keywords
Territorial disparities; Territorial exposure; Industrial agglomerates; Urban and regional planning; Tuscany.

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1. Introduction

Urban settlements have industrial spaces as one of their fundamental substructures. It is inside these places of production that the values destined to sustain and reproduce urban economies, commercial exchanges, and to support other economic activities are created (Lefèbrve, 1974). On this assumption, it is logical to associate industrial activities' dynamism to the processes of growth and decline of other urban functions, such as residential areas or shopping complexes production, in a manner that defines the industrial agglomerates as the real and proper drivers of modern urban development (Lefèbrve, 1974 and 1996). In this sense, industrial activities' location within territories possesses a recursive role regarding built-infrastructures organization: the industrial activities will be located near important market nodes (cities) and their development will have an influence on the successive industrial agglomerates' growth, as well in further public policies of investment in urban infrastructure, in a circular and reiterative relationship. Even though desired from a developmental point of view, these relations tend to also to increase territorial disparities. These asymmetrical regional development patterns can lead to a condition of underuse or abandonment of potentially productive spaces, which result in the urban environments' *exposition* to grave socio-economic pressures (Smith, 2008), such as unemployment and populational decrease.

This interdependence between spatial localization and production was quite discussed since the seminal works on territorial economics were published during the 1920's, both assessing regional (Weber, 1929; Nijikamp, 1986) and urban (Alonso, 1964; Mills, 1987) contexts. Nevertheless, economics' analytical efforts have been, since then, restricted to comparative evaluations of location within macro-territorial scales, above all, focused on microeconomic repercussions, in terms of productive returns and growth, interpreted as derived from economic activities' *geography* at urban – with bid-rent theory (Cheshire and Mills, 1999) – and regional scales – through spatial equilibrium, input-output and agglomeration analysis (Henderson & Thisse, 2004; Duranton et al., 2015a, 2015b). These formalistic analyses predominance and the historical detachment amid economic and territorial studies after the 1970's conduced to a limited development of spatial analyses capable to describe with sufficient detail how disparities in territorial endowments (built-spaces characteristics) affect economic activities – as space is often interpreted in economics as an *abstracted* background. The *abstracted* spatial representation can be identified as one of the issues for the evident discontinuities in spatial knowledge and models' progress in the Urban and Regional Economics field, as classical principles and theories of location developed during the 1920's (Capello, 2015), as well as comparative territorial models with limited spatial detail – such as locational quotients *(shift-share* models) (Fracasso et al. , 2018; Bellandi et al., 2019) – are still revered, being used on most economic-based territorial analysis. Hence, economics' reluctance in the adoption of novel instruments and computational methods that assess space with a greater level of detail, as those developed for use in Geography, Urban and Regional Planning and Territorial Engineering and Risk Assessment (Francini et al., 2020; Di Ludovico et al., 2021), has left several spatial-economic relations among production systems, the spatial configuration of infrastructural networks, and the organization of industrial agglomerates fundamentally unexplored.

In this aspect, innovative models capable to assess the complex behaviours and the disparities within industrial territories placed on urban-regional settings are dependent of a transformation in how economics understand space and interpret spatial knowledge. This achieves an unprecedented relevance, as surpassing the analysis limitations of Urban and Regional Economics' spatial models is fundamental to the successful outcome of post-crisis economic recovery policies, above all, following territorial constrains due to lockdowns and the serious recession period decurrent of the Covid-19 pandemic (Campagna, 2020). With these issues in consideration, this paper objective is to advance in the development of spatial-economic models, suitable to highlight the spatial distribution and territorial disparities within industrial agglomerates on urban and regional systems. For this purpose, the proposed model assesses a condition defined as *territorial exposure*, evaluated through analysis of the Tuscany regional structure. The conceived concept of *exposure* – determined by a parametric index – denotes how the territories' built-spaces support the industrial agglomerates and highlights disparate territorial endowments, that are identified as factors of spatial sensitivity to the firms and may affect their capabilities to interact and react to periods of economic recession and their post-crisis recovery. The spatial knowledge produced can aid the regional initiatives for economic recovery directed to Tuscan industries.

2. Datasets and Methods

The data extraction processes, and the datasets used in the evaluation of Tuscan territorial disparities are described in the section 2.1. To be suitable for spatial-based correlations, these datasets are organized into a GIS suite (QGIS, 2020). Several geoprocessing steps are needed to perform data treatments needed to assess the industry territorial patterns through *Macroarea* and Configurational Analyses; those are outlined, together with the parameters used for the *Territorial Exposure Index (TEi)* construction, in the methods section (2.2).

2.1 Datasets organization

Spatial information on the industrial assets used in the *Macroarea* Analysis construction, to assess the territorial size, and dynamics of industrial placement, is extracted from the Tuscan Region Built-Structures dataset *(Edificato 2k,10k 1988-2013)* (Regione Toscana, 2019a). This database outlies the location of all built-structures throughout the territory, represented by volumetric units (polygons), categorized according to their main urban function. The information contained on the dataset is multiscale, meaning that it is assembled from different Technical Charts (scales 2k and 10k), and periodic, thus collected over a time-period comprised between 1988 and 2013. For this analysis purpose, only volumetric units that are categorized under "Industrial" *(Industriale)* or "Technological Plant" *(Impianto Tecnologico)*, and that are listed as "active" in the 2013 period, are considered as industrial assets, which are exported from the main dataset.

The road-infrastructure dataset employed in the Configurational Analysis, that model road-circulation network movement dynamics, derives from the Tuscan Region Road Graph *(Grafo Stradario della Toscana)* (Regione Toscana, 2019b), a Road-Centre Line (RCL) graph map that represents the entire regional road-infrastructure. Road-elements were further generalized through QGIS integrated Douglas-Peucker algorithm (QGIS, 2020; Altafini & Cutini, 2020), to diminish the total number of vertices and reduce the extensive network modelling time-lapses for Space Syntax' Angular Analysis (Turner, 2001). Angular Analyses are able to assess different kinds of network parameters, related to urban-regional centralities hierarchies, therefore, are able to estimate several movement dynamics within the road-infrastructure system, through Normalized Angular Integration - NAIN *(mathematical closeness centrality)* and Normalized Angular Choice - NACH *(mathematical betweenness centrality)* configurational measures (Hillier et al., 2012). For this analysis purposes, only the latter measure is considered. Since *betweenness centrality* counts, for all origin-destination pairs, the number of times each road-element is traversed when travelling through the overall shortest path towards all potential destinations (Turner, 2001), the NACH measure is capable to depict the *preferential routes* hierarchies used in regional transport connections, important factor to be considered regarding industrial activities placement.

2.2 Methods for evaluating territorial disparities

Several steps of geoprocessing are required to assess industrial assets' distribution and territorial disparities. While each step can be considered as an independent territorial analysis, since it addresses a particular spatial factor, two collective assessments can be summarized: the *Macroarea* Analysis, that, based on industrial assets' placement, considers the industrial *macroareas*' size, degree of industrialization and agglomeration patterns within a certain part of the territory; and the Configurational Analysis, that highlights the regional-wide preferential transport routes of the road-circulation network. The parameters/indicators of these analysis are combined, and result in the Territorial Exposure Index (TEi) – which evaluates the spatial patterns and differences in endowments that can lead to economic unsoundness from a territorial standpoint. The Territorial Exposure Index (TEi) is constructed through the attribution of scores for parameters determined through the *Macroarea* and Configurational Analyses, that individuate the following variables, described in Equation 1: the *macroareas* size (Si) and the agglomeration index degree (Ai), given by the industrial assets' positional analysis; and the road-configuration parameter (Ri), that is established through correlations between *betweenness centralities* values and the industrial assets, and depict their nearness to *preferential routes.*

$$TE_i = S_i + A_i + R_i \quad (1)$$

As an initial step to construct the *Macroarea* Analysis, an industrial spaces' dataset is created from the industrial assets' volumetric units to establish the spatial linkages among industrial assets placed in the same on in near plots of land. The procedure draws a 30m buffer radius – equivalent to the plot plus the street area – for each volumetric unit, then dissolved into continuous areas. The result, a sole spatial unit (Fig.1a), is submitted to a negative buffer, that reduces the excess areas created through the positive buffer into the original industrial assets' dimensions, while maintaining the area boundaries and contiguities established by the buffer (Fig.1b). The industrial spaces are then individualized, through the conversion into single parts from the sole territorial unit, that are then categorized according to their area size (Tab.1, Figg.1a; 1b; 2).

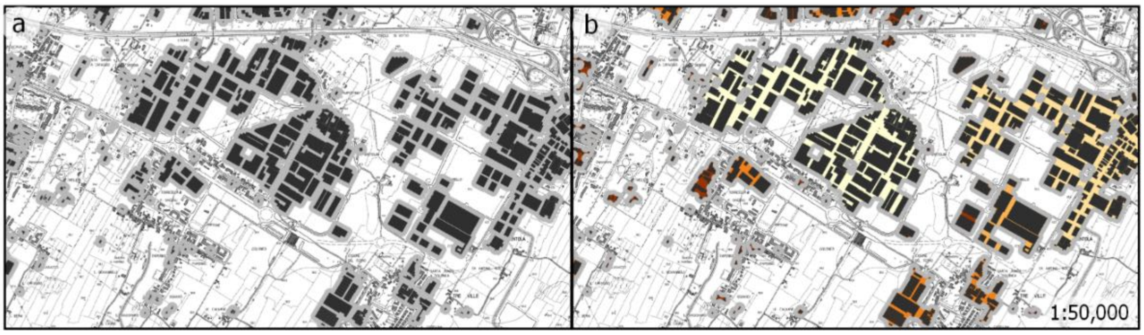

Fig.1 Industrial spaces creation from industrial assets: positive (a) and negative (b) buffer results, with area categorization

Classification	Industrial Assets Count	Industrial Spaces Count	Total Area [km²]	Buffer radius [m]	Buffered surface [km²]
Maximal (>= 0.6 km²)	2,118	4	4.73	100	9.44
Large (>= 0.2 - < 0.6 km²)	6,914	38	11.98	200	47.29
Medium (>= 0.075 - < 0.2 km²)	9,062	128	15.33	300	131.71
Small (>= 0.02 - < 0.075 km²)	16,780	623	23.34	400	591.33
Minimal (< 0.02 km²)	45,319	14,901	27.60	500	12,741.37
Total	80,193	15,694	82.98	-	13,521.14

Tab.1 Tuscany industrial spaces classification regarding count, total area, relative multi-distance buffer and total surface after buffer

Industrial spaces are considered as base features to draw multi-distance buffers from each of the single parts (Fig 2). This differentiation in radius is enacted to reflect general characteristics of a particular industrial space regarding internal and external displacement tendencies towards regional transport routes. Larger industrial spaces tend to require a greater internal displacement to reach regional *preferential routes* – hence a smaller buffer radius, while smaller spaces tend to require greater external displacements – thus a greater radius.

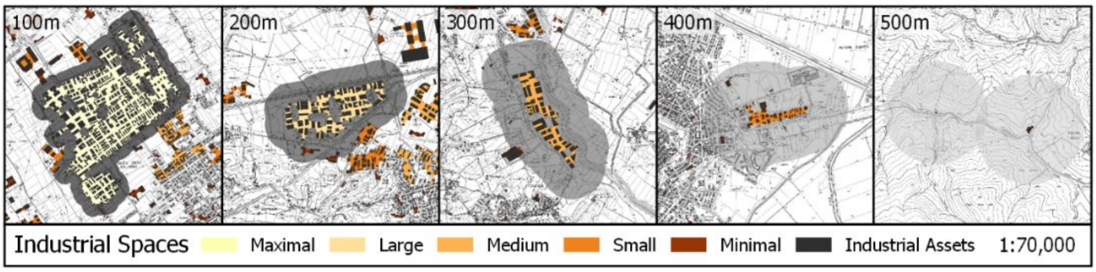

Fig.2 Examples of categorized industrial spaces with their respective buffer distances applied

Areas created through the multi-distance buffer are dissolved to form continuous *macroareas*, that are divided into single parts based on their contiguities, and categorized according to: size, industrial spaces (contiguous spaces) and industrial assets (structures) counts (Fig.3a, Tab.2). *Macroareas* are conceptualized to establish a visual representation of Tuscan industrial assets' territorial cohesion and distribution, their industrialization patterns (industrialization degree), and to highlight the displacement reach of the collective industrial spaces. The ratio between the number of individual industrial spaces and the number of industrial assets located within a *macroarea* yields an agglomeration index (Fig.3b, Tab.3), that illustrate industrial assets' overall degree of agglomeration and depicts the industrial spaces' usage (average industrial assets' density). This index performs a supportive role to the macroareas spatialization that, nevertheless able to depict the territorial dimensions of industrialization, is unsuited to address the proximity conditions among industrial assets within a same territory. The *macroareas*' size (Si) (overall cohesion and industrialization) and the agglomeration index (Ai) are used as parameters to define the economic activities spatial patterns considered for the Territorial Exposure Index (TEi).

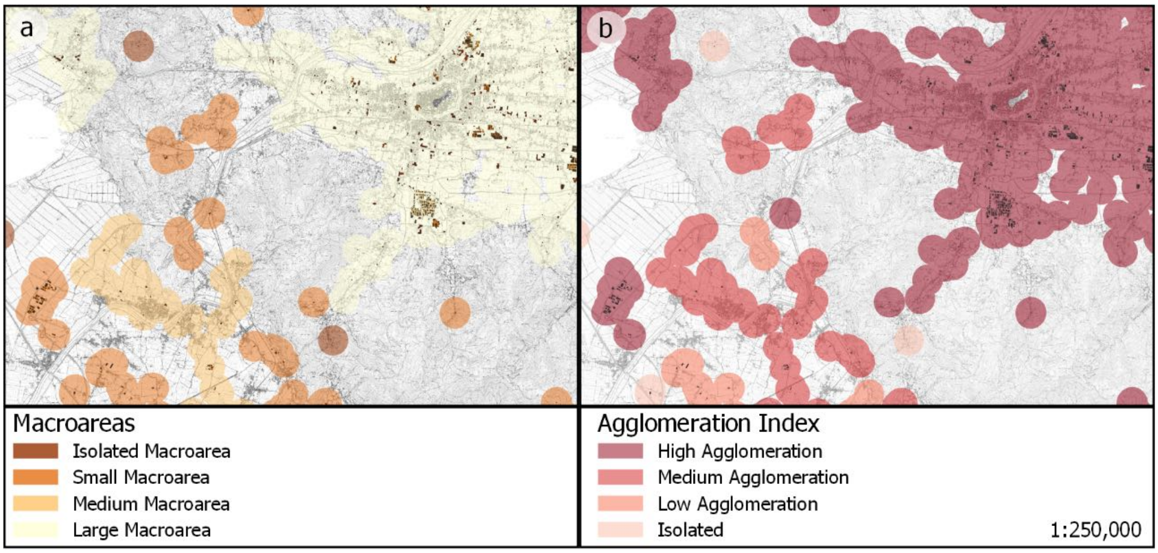

Fig.3 Comparison between Macroareas (a) and Agglomeration Index (b)

Classification - Size	Industrial Assets Count	Industrial Spaces Count	Area Range [km²]	Macroareas Count
Isolated Macroarea	1	1	< 5.00	435
Small Macroarea	> 1	> 1	< 5.00	862
Medium Macroarea	> 1	> 1	>= 5.00 – < 100.00	87
Large Macroarea	> 1	> 1	>= 100.00	3

Tab.2 Macroareas size classification according to industrial spaces count, industrial assets count and area value ranges

Classification - Degree	Agglomeration Index Range	Macroareas Count
Isolated	1.000	591
Low Agglomeration	> 1.000 – >= 0.750	49
Medium Agglomeration	< 0.750 – >= 0.250	578
High Agglomeration	< 0.250	169

Tab.3 Agglomeration Degree classification, according to agglomeration indexes value ranges

Configurational analysis provides another parameter used in the Territorial Exposure Index (TEi) construction, yet it can stand as an independent analysis as well, as it addresses the road-infrastructure system dynamics. Normalized Angular Choice (NACH) is a *betweenness centrality*-based network measure that establishes and depicts the road-elements' hierarchies based on their probability of usage as a through-movement route (Fig.4a). In this aspect, core centralities, represented by the NACH highest values, highlight the *preferential routes'* structure that constitutes the main linkage-paths between different areas within the regional road system. To establish spatial correlation among the *macroareas* and the *preferential routes*, and assess the industrial assets nearness to them, betweenness centralities values are restricted in the visualisation to their core centralities, equivalent to NACH values that range from 1.00 to 1.47 (top 20% road-elements) (Fig.4b).

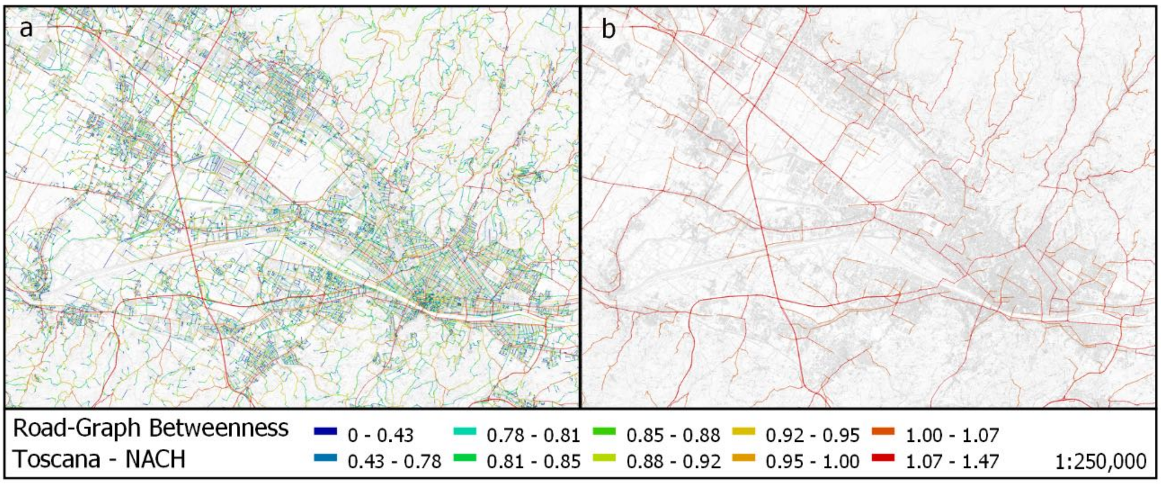

Fig.4 Road-circulation network betweenness centralities' hierarchies (a) and restrcted *preferential routes* structures (b)

Spatial correlations occur when a road-element within the specified value range (1.00 to 1.47) intersects at any point with a *macroarea*. Therefore, this relation means that the cohesive territorial extent in question – and the industrial spaces and assets within it – is near enough to a road-element that, considered the overall displacement predisposition, represented by the *macroarea* reach, provides access to a main transport axis *(preferential route)*, hence, to the remainder of the regional road-circulation network. The road-configuration parameter (Ri) is established as a Boolean variable in the TEi, being interpreted as a *true* or *false* given the presence or absence of correlation.

The partial parameters of *macroareas* size (Si), agglomeration index (Ai) and road-configuration (Ri) compose the Territorial Exposition Index (TEi), in accordance with the relation previously defined in Equation 1. The TEi is defined through the simple sum of the partial parameters scores, that are attributed according to the degree of territorial support provided by each parameter subcategorization. TEi values sums range from minus three to five and will correspond to a defined degree of exposure. Negative values obtained as results from this sum are defaulted to zero, therefore, categorized in the *very high* class of territorial exposure; values in which the sum is over four are instead included in the *very low* class of territorial exposure (Tab.4, Fig.5).

Parameter	**Scores**	**Macroarea Count**	**Industrial Assets**	**I.A. (%)**
Macroareas Size Parameter – Si				
Isolated Macroarea	-1	435	435	0.54
Small Macroarea	0	862	9,043	11.28
Medium Macroarea	1	87	23,389	29.17
Large Macroarea	2	3	47,326	59.02
Agglomeration Degree Parameter – Ai				
Isolated	-1	591	838	1.04
Low Agglomeration	0	49	353	0.44
Medium Agglomeration	1	578	8,331	10.39
High Agglomeration	2	169	70,671	88.13
Road-Configuration Parameter – Ri				
No Spatial Correlation with a Preferential Route	-1	59	111	0.14
Spatial Correlation with a Preferential Route	1	1328	80,082	99.86

Tab.4 Territorial Exposure Index parameters scores and count for each variable

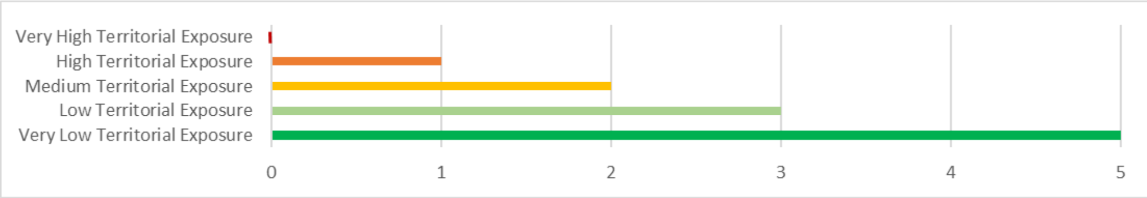

Fig.5 Territorial Exposure Index scores color graph and respective degree of exposure

The index establishes the degree of territorial exposure for each *macroarea*. The *exposure* concept is defined as the amount of support that the territorial context – the built-structures' cohesion, their agglomeration, and the nearness to the road-infrastructure's *preferential routes* – provides to the industrial activities operation. Hence, the parameters are tailored to consider how industrialized the territory is *(macroareas'*s cohesiveness and size), and how and how close in organization the industrial assets are to each other (their degree of agglomeration) – aspects that contribute to facilitate local interindustry relations; as well as their access to other industrial agglomerates (road-infrastructure correlation) that allows movement of people and production. In this regard, differences in territorial exposure indicate what are the disparities in the territorial framework, in terms of infrastructure, organization and overall cohesiveness. These endowments can, if present, contribute to industrial dynamism and resilience, by providing better conditions for industries to interact and compete; and, if absent, lead to these spaces underuse or outright activity abandonment under economic recession conditions, due to the insufficient support from the territories or other local productive agglomerates within the region, that in a situation of restriction of supply – or movement of goods and people – may hinder industrial function.

3. Results and Discussion

Although a partial outcome from the collective spatial analysis that results in the territorial exposure evaluation, the industrial *macroareas* spatialization reveal clear territorial disparities in the Tuscan industrialization that, to some extent, mirrors the Italian north-south dualism (Fig.6).

Septentrional Tuscany locates all three large *macroareas*, cohesive spaces of industrial presence, that on their own encompass 59.02% (47,326) of the total regional industrial assets – structures dedicated to production. Traced a divide in central Tuscany, and considered the remainder of medium, small and isolated *macroareas,* 83.41% (66,891) of the industrial assets are placed in northern Tuscany, hence, by far, being its most industrialized territory. These spaces of production tend to decrease in overall size, cohesiveness and quantity towards central and meridional Tuscany, a circumstance that outlines the sparse industrial presence in the south, where small and isolated *macroareas,* that comprise, respectively, 11.28% (9,043) and 0.54% (435) of the total regional industrial assets are prevalent. Such sparse industrial distribution characterizes the *Maremma* area, within the Grosseto province, and illustrates the remarkable disparities in industrialization amid northern and southern Tuscany. Albeit several medium *macroareas* are present in the around the city of Grosseto, and in punctual locations throughout the *Maremma* area, this territory is mostly comprised of small and isolated industrial *macroareas* that correspond to only 1.72% (1,359) of the total regional industrial assets. Likewise, it is distinguishable that the *preferential routes* network become few and far between in southmost *Maremma*, especially when compared to the interconnected central and northern Tuscany road-infrastructure (Fig.6), a territorial feature that contributes to the increase of these areas' exposure, since communication and access to the larger industrial areas is hindered.

Medium *macroareas* encompass 29.17% (23,389) of the total regional industrial assets. Despite a prevalence in septentrional Tuscany, their presence within central Tuscany is rather significant around the *preferential* routes that extend towards the south, that marks the transition in the Tuscan patterns of industrial distribution – and territorial disparities. Important industrialized spaces are set in the central Tuscany; an example are the productive territories placed in *Valdichiana*, area located in-between the *Arezzo* and *Siena* provinces, that exhibit a compact group of medium *macroareas*. Collectively, these incorporate 20.98% (4,908) of the total industrial assets within medium *macroareas*, and 6.12% of the total regional assets, hence, having greater industrial presence than other important individual medium sized productive areas, such as those located in-between the *Pisa-Livorno* area in septentrional Tuscany, or in the *Chianti* area, that extends across the *Firenze* and *Siena* provinces in central Tuscany (Fig.6).

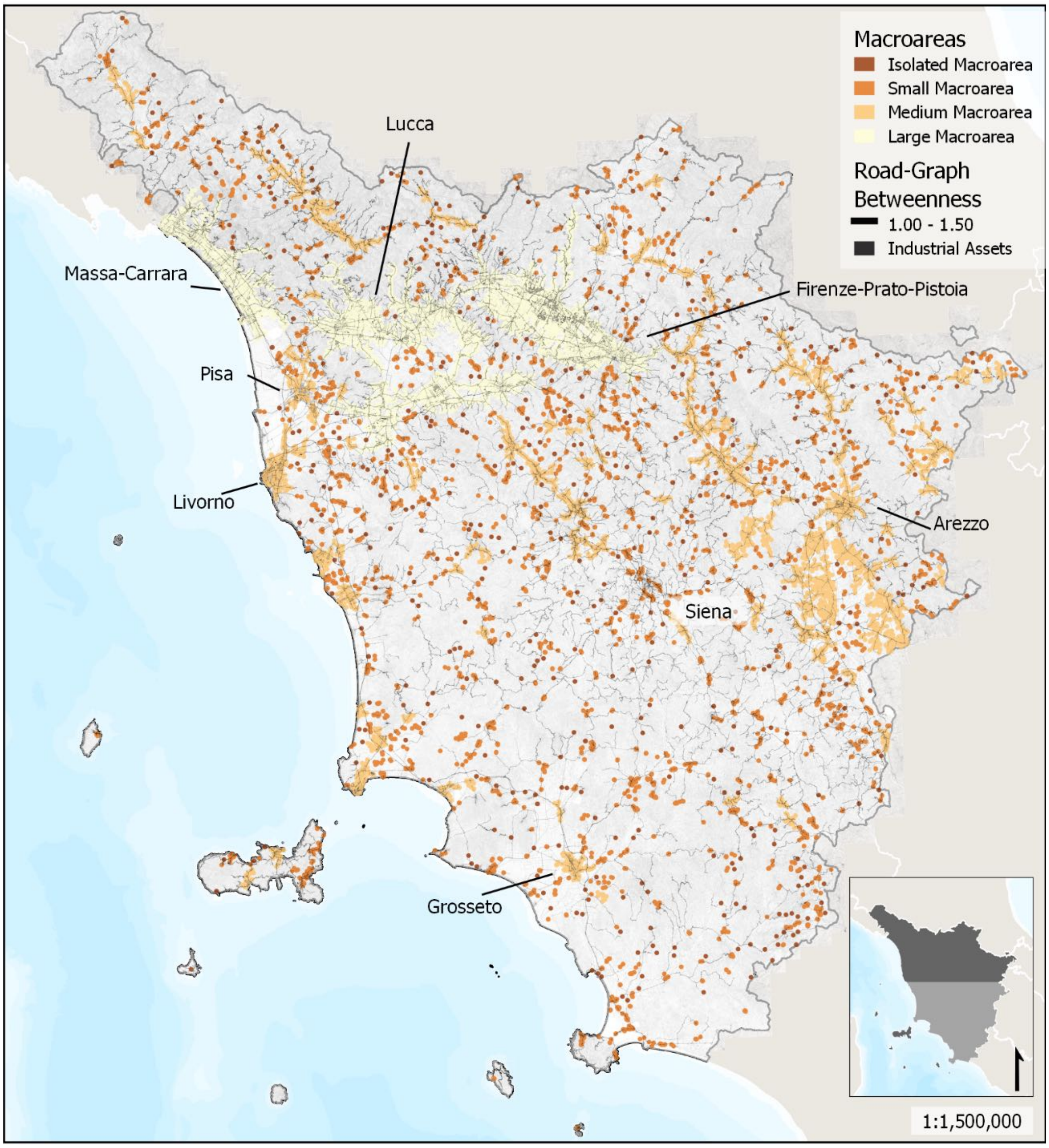

Fig.6 Macroareas placement and *preferential routes* distribution across the Tuscan territory

Regardless of their condition as the most industrialized cohesive spaces in Tuscany, the large macroareas still conserve several territorial disparities when compared to each other (Fig.7) Located along the *Versilia* coast, the smallest of these *macroareas* comprises the *Lucca* province littoral towns, that locate small sized industrial assets; and extends towards the cities of *Massa* and *Carrara*, where the larger industrial spaces are set (Fig.7a). Notwithstanding its considerable dimension (226.4km²) – over a third of the largest sized macroarea – the *Versilia* possesses only 16,69% (7,901) of total industrial assets (47,326) located within large *macroareas*. This distinctive feature can be explained through the observation of its industrial spaces' average size and distribution. In this *macroarea*, the industrial structures are smaller, therefore, their dissolution in single areas

results in reduced industrial spaces with larger buffer reaches; their displacement, however, is interleaved along the highways that cross the *Versilia coast*, which results a rather contiguous productive agglomerate.
In contrast to the *Versilia* productive space, the largest macroarea (588.37km²) – henceforth denominated as *Valdarno* – extends throughout the Arno River Area (*Valdarno*) and the *Lucca* and *Pistoia* plains, therefore comprising several urban settlements between *Lucca*, *Pisa, Pistoia* and *Firenze* provinces (Fig.7b). The *Valdarno* macroarea contains 36.89% (17,428) of the total industrial assets within the large *macroareas*, which corresponds to 21.73% of all industrial assets within Tuscany (80,193). The larger industrial spaces are sited in-between the *Pisa* metropolitan area and the *Empoli* urban area – in close relation to the Fi-Pi-Li, a main highways that connects *Firenze, Pisa* and *Livorno*; while the *Lucca-Pistoia* area has a more diffuse industrial distribution, marked by smaller industrial assets, also in close position to the road-infrastructure. In this aspect, even if the industrial placement logic is quite similar to the one found in the *Versilia* macroarea, with industrial spaces located near the regional road-circulation network *preferential routes*, there is a noticeable difference in the industrial assets' quantity, overall industrial spaces' size and agglomerative patterns, which lead to a larger industrial cohesive agglomerate.

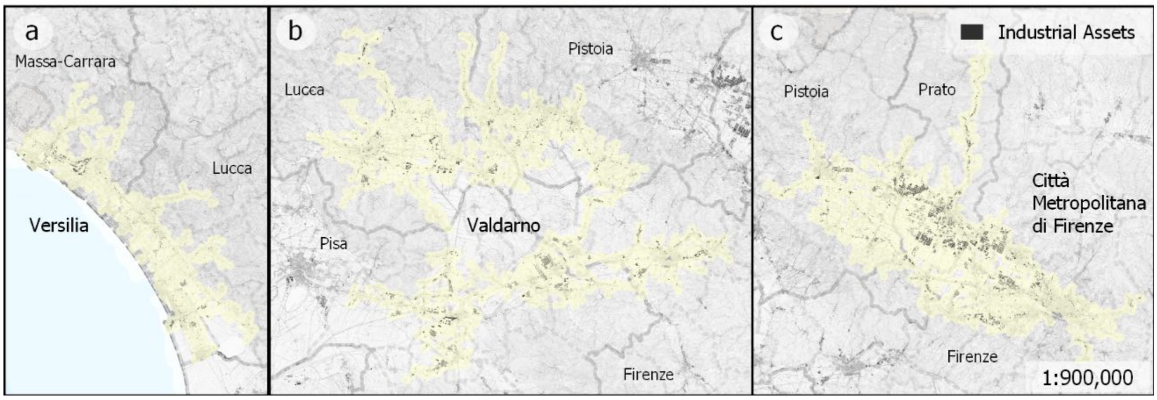

Fig.7 Large Macroareas of *Versilia* (a), *Valdarno* (b) and *Città Metropolitana di Firenze* (c)

The *Città Metropolitana di Firenze* (Florence Metropolitan City) *macroarea* (Fig. 7c) possess a territorial extent of 438.92km² and, although smaller than the *Valdarno macroarea*, it consists in the most industrialized space within Tuscany. This cohesive industrial agglomerate spans throughout the provinces of *Firenze, Prato* and *Pistoia* (Fig. 7c) and encompasses 46.48% (21,997) of the total industrial assets within large *macroareas*, being equivalent to 27.43% of the total regional assets. Most of these assets, however, are not located within the main provincial urban centres – that have a sparse industrial presence – but instead are placed on industrial districts on metropolitan area boundaries. Such distinctive spatial organization results in significant differences when the industrial spaces within the *Città Metropolitana di Firenze macroarea* are considered, especially when compared to the ones present in *Versilia* (Fig.7a) and *Valdarno* (Fig.7b) *macroareas*. Given the compact nature of the industrial assets' distribution within this territorial extent – with a noticeable concentration in-between *Firenze* and *Prato* provinces – the industrial spaces tend to have a greater number of industrial assets established within them, while maintaining average sizes. This results in a higher agglomeration degree due to the presence of more productive-oriented structures in each industrial space.
Agglomeration is a crucial variable in the territorial exposure assessment. The average density of industrial assets within an industrial space can give indicatives about the industry size, as well as the amount of economic support that is provided by interindustry relations among nearby firms, factor that contributes to local industrial aggregates dynamism. Agglomeration analysis has a supportive role to the *macroareas* spatialization that, nevertheless able to depict the territorial dimensions of industrialization, is unsuited to address the proximity conditions among industrial assets within a same territory. From a regional perspective, what emerges from this analysis is, once again, the dualism – albeit in this case, less prominent – amid northern and southern

Tuscany (Fig.8), as territorial disparities in agglomeration still follow patterns similar to those verified through *macroareas* spatialization.

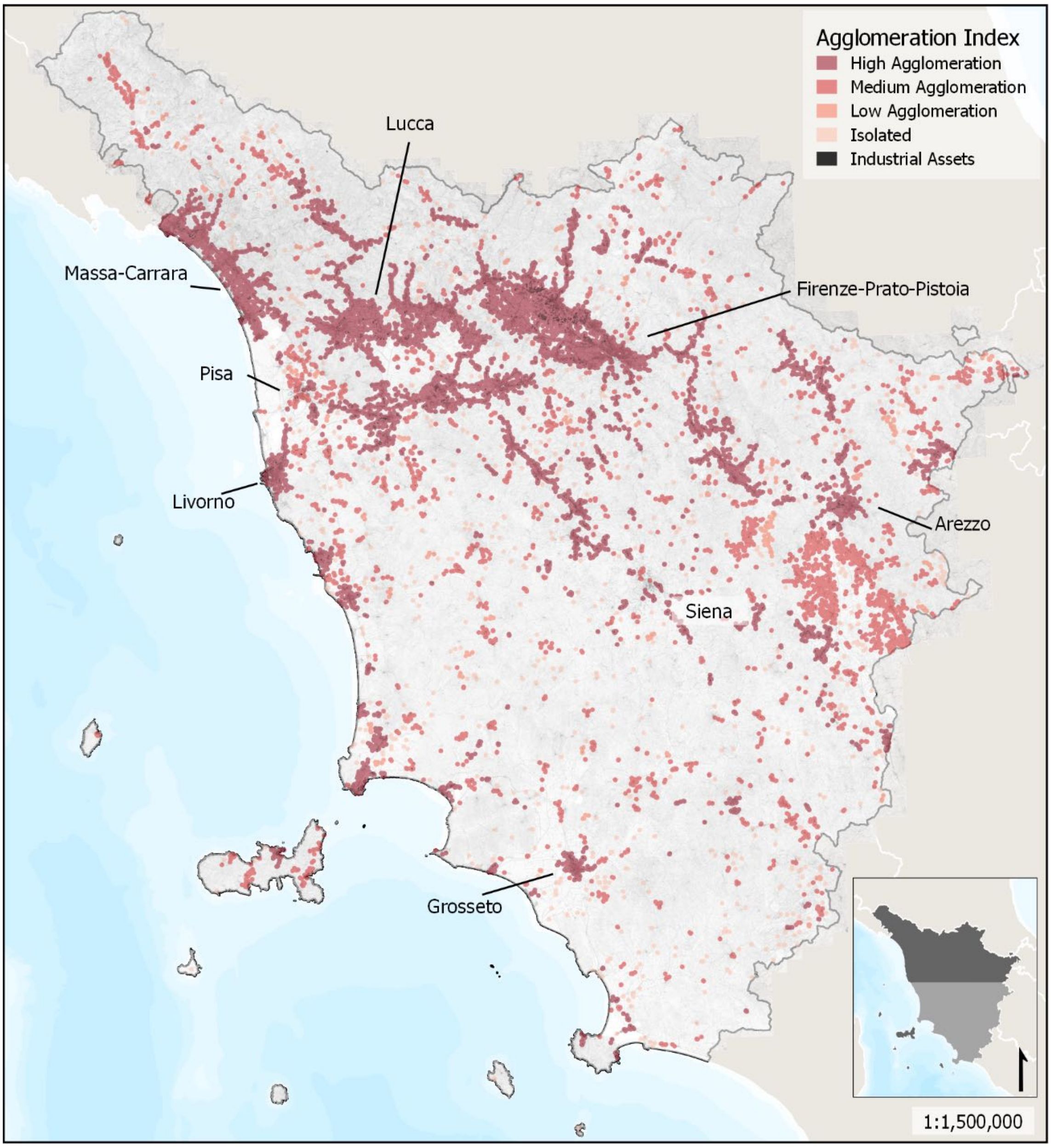

Fig.8 Industrial assets agglomeration degree across the Tuscan territory. Source: *Regione Toscana - Edificato 2k,10k 1988-2013*

Despite a certain equilibrium in distribution, septentrional Tuscany amass most of the *macroareas* (55.96% - 113 of 202) classified within the high agglomeration range. This condition, however, is not particular to the large or medium cohesive production spaces, that encompass only 23.89% (27) of this total, but is prevalent on small *macroareas*, which amount to 76.11% (86) of the northern-based *macroareas* within the high range (Fig.8). Overall agglomeration tends to decrease beyond central and towards meridional Tuscany, where areas with medium to low agglomeration indexes are predominant (. These areas, comprised by small and medium *macroareas*, are located near *preferential routes* that cross the Tuscany hinterlands, and adhere to the size logic verified in the previous analysis, as isolated *macroareas* – that exhibit no agglomeration – become more prevalent in the septentrional and central hinterlands, in addition to meridional Tuscany (Fig.8).
Comparison of absolute values for agglomeration reveals that, although large *macroareas* possess high values (over 0.80), medium and small *macroareas* are those that exhibit the highest agglomeration indexes (over 0.90). Further examinations reveal that the cause for this discrepancy is the presence of sparsely distributed

industrial spaces in the larger *macroareas*, with few or single industrial assets within them – a remarkable trait of the *Versilia* macroarea (Fig.9a) – that diminishes otherwise high overall industrial assets' densities. Some medium *macroareas* exhibit similar patterns, as observed in the groups of *macroareas* placed in the *Valdichiana* (Fig.9b). In this context, small and medium *macroareas* in northern – but, above all, in central Tuscany – that structured by few, compact and densely occupied industrial spaces, are those that possess the highest degrees of agglomeration. Instances where this patten can be verified are in the production spaces in-between the *Valdelsa* (Elsa River Valley) and the *Chianti* productive areas (Fig.9c), as well as in small *macroareas* placed in close relation to road-circulation network *preferential routes* (Fig.8).

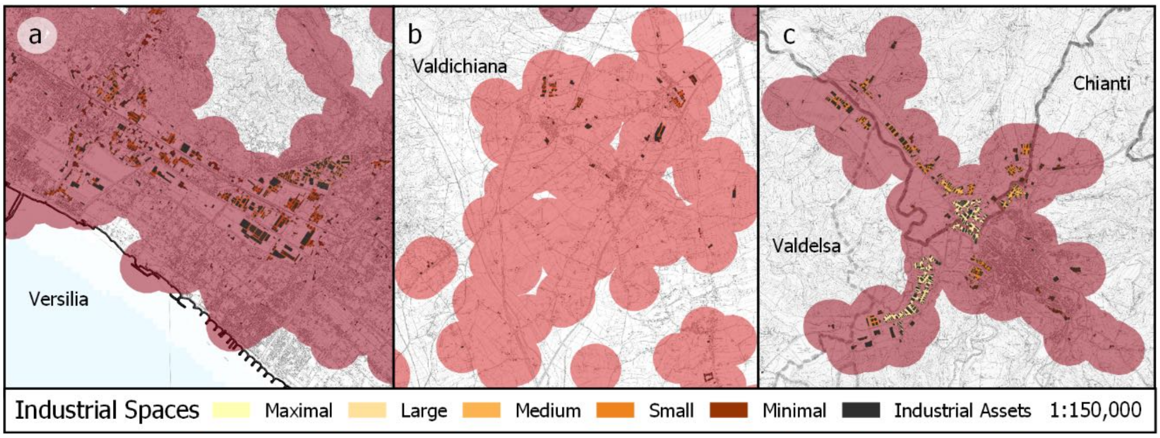

Fig.9 High agglomeration in the *Valdelsa* (a), *Chianti* (b) and *Valdichiana* (c) macroareas

Furthermore, the examination of absolute values for agglomeration reveals that *macroareas* located within the immediate boundaries of large urban centres often exhibit higher agglomeration values, in comparison with the *macroareas* that compose the city area – a peculiarity quite noticeable in the *Pisa* metropolitan area (Fig.10) – but also in other urban areas such as *Grosseto* and *Arezzo* provinces (Fig.8). Beyond those boundaries, agglomeration values are prone to decrease towards the hinterland areas, as industrial assets become sparse.

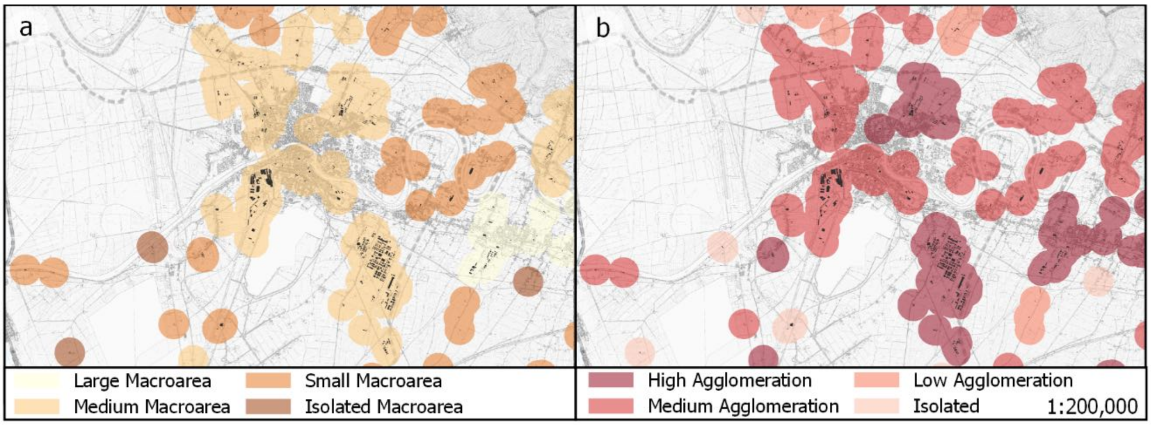

Fig.10 Comparison between macroareas size (a) and agglomeration analysis (b) for the Pisa area

The Territorial Exposure Index (TEi) construction and spatialization reveals that the disparities in exposure lie beyond the distinguishable north-south divide, highlighted in the previous analysis as a characteristic that represents the transition in *macroareas'* size and industrial agglomeration (Fig.6; Fig.8). From a regional standpoint, the condition of territorial exposure can be associated to specific local differences in the territorial endowments that exist amongst *macroareas* placed in proximity to urban centres and *preferential routes* and those located in the hinterlands, which have sparse concentration of industrial structures, as well as less infrastructural support (Fig. 11). In this context, it becomes evident that the agglomeration degrees have a significant influence over regional exposure patterns and consist in the main differentiation factor for variations in TEi values within *low, moderate, and high* index ranges, above all, among medium and small *macroareas.* Hence, industrial agglomerates that would otherwise possess analogous characteristics, given their similar *macroarea* size, degree of industrialization and nearness to *preferential routes*, unveil important disparities when industrial assets' agglomeration is considered (Fig.6; Fig.11).

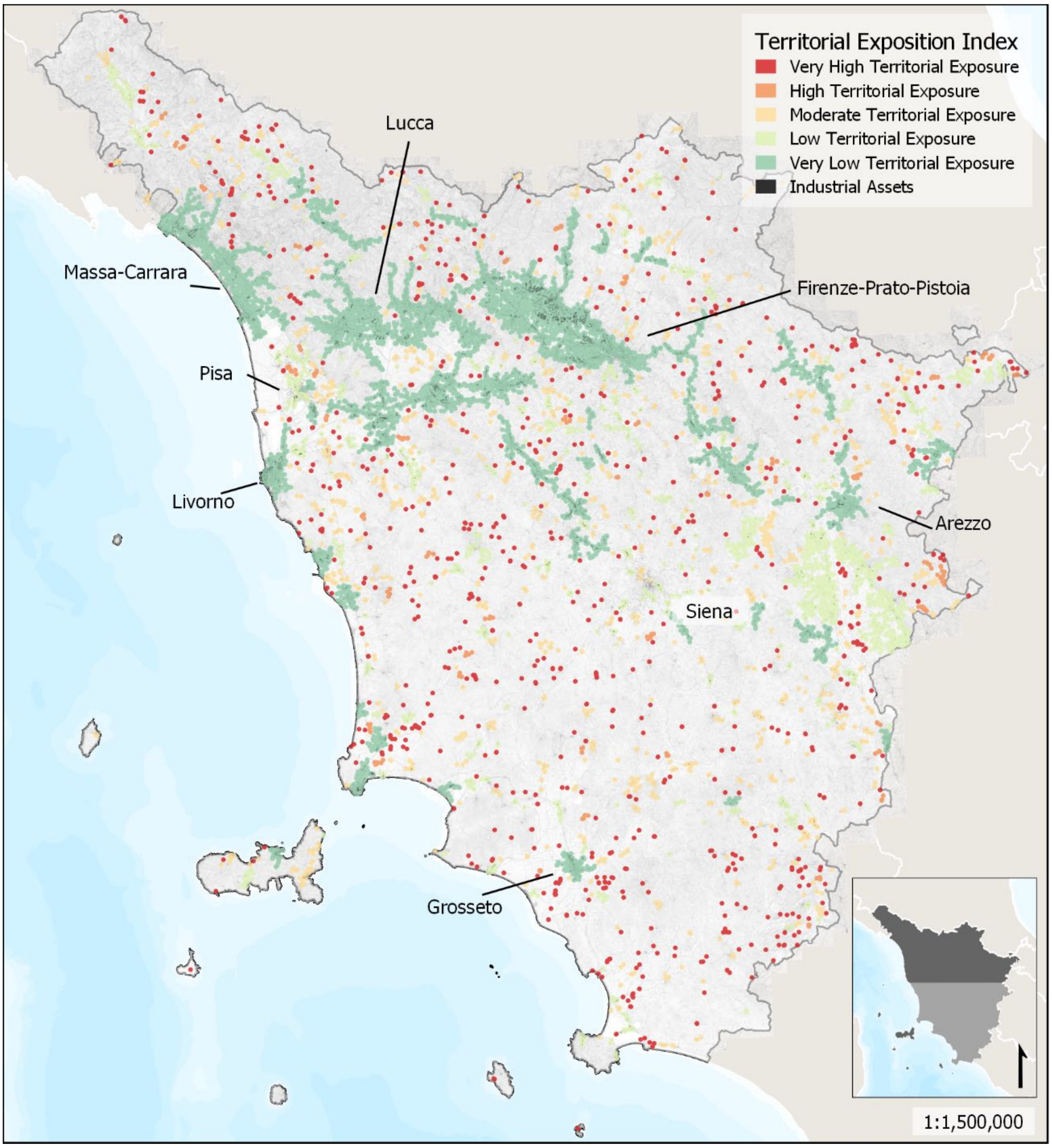

Fig.11 Territorial exposure degree and territorial disparities across the Tuscan territory

Notwithstanding an evident prevalence of industrial agglomerates possessing *low* and *very low* territorial exposure in septentrional Tuscany (Fig.11), space that comprehends, respectively, 52.42% (108 of 206) and 65.85% (27 of 41) of the total *macroareas* within these categories, the increased ranges for territorial exposure possess a rather even spatial distribution. Territorial disparities' analysis observe that Meridional Tuscany encompasses 51.66% (291 of 602) of the *macroareas* in the *very high* range of territorial exposure. When the *high* exposure ranges are considered, it is instead northern Tuscany that locates the majority of the industrial agglomerates, with 59.18% (29 of 49) of the total *macroareas* within this category; a similar proportion, 55.21% (270 of 489), is also verified for the *macroareas* within *moderate* territorial exposure range. While differences between *low*, *moderate and high* exposure are mostly due to different agglomeration degrees, the ones regarding *high* and *very high* ranges can be also attributed to *preferential routes' absence*. In this case, small *macroareas* that possess medium agglomeration degrees – and would otherwise have a *moderate* degree of exposure if only agglomeration and size were considered, tend to have a higher exposure, due to not being sufficiently near to the main *preferential routes*, thus resulting in a diminished territorial support.

From this perspective, the influences of industrial assets' agglomeration and, to a lesser degree, the nearness to *preferential routes* become quite perceptible. In the example of *Pisa* metropolitan area (Fig.12) it is possible to notice that *macroareas*, that have lower industrial assets' agglomeration, tend to have a higher exposure condition, with degrees' varying according to their size and cohesion (Fig.12a; Fig.12b). However, it is also noticeable that, when this lower agglomeration is associated to an absence of access to the road-infrastructure, the exposure degrees are aggravated (Fig.12b). This restricted accessibility to *preferential routes* leads to a deficient state regarding the connection to nearby industrial agglomerates, a condition that may hinder both interindustry relationships and further industrial expansion of those areas, as industrial placement tendencies have positive correlations with the road-circulation network centralities (Altafini et al., 2021). In this aspect, firms will avoid placement in areas that are *segregated* in terms of infrastructural linkage, consequently leading to the development of greater territorial disparities in long-term.

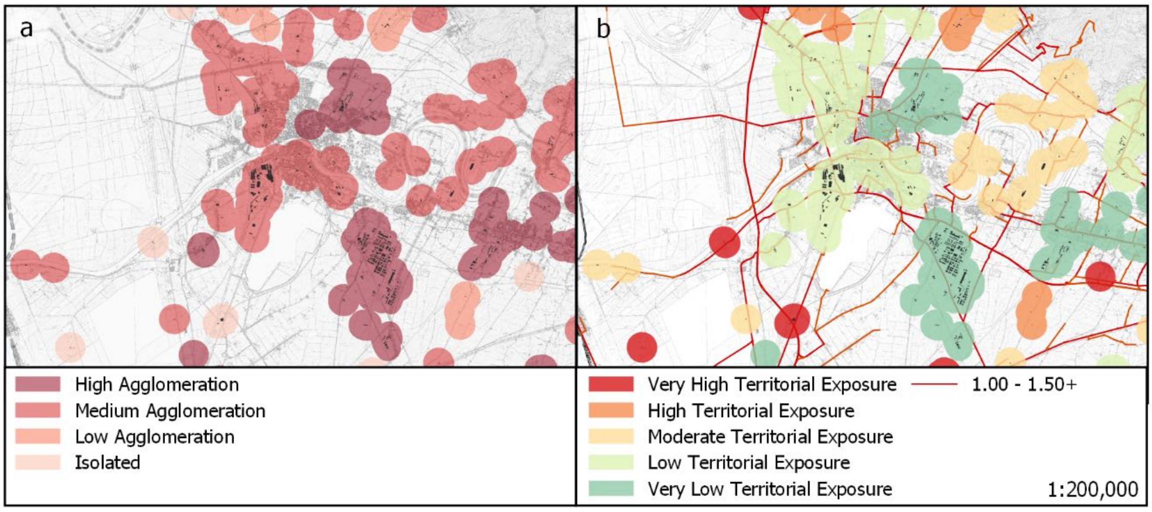

Fig.12 Comparison between agglomeration analysis (a) and territorial exposure index (b) for the Pisa area

In terms of economic dynamism, lower local industrial presence can lead to weaker interindustry relationships; this, when associated to the absence of connection to other industrial agglomerates, contributes to a reduced support network from other local firms placed throughout the region. These could serve as a lifeline in terms of supply and demand for produce, in the advent of an economic recession, stagnation of one industrial sector, or limitations in the global supply chains availability due to territorial restrictions – as the one ensued during 2020 and 2021, during the Covid-19 pandemic. Overall, the territorial exposure condition indicates that the disparities on territorial endowments can compromise certain aspects related to the industrial agglomerates' resilience, therefore, certain areas are in a greater risk of being unproductive under economic constrains, that can ultimately can result in their underuse or abandonment.

With these results in consideration, although it is possible to affirm that meridional Tuscany has fewer industrial agglomerates within lower ranges *(low* and *very low)* of territorial exposure, and that the *very high* degree of exposure is prevalent in the south, since more isolated industrial agglomerates are present, it is erroneous to uphold that the south has an overall higher exposure condition. If absolute numbers of industrial agglomerates within the ranges of *moderate, high* and *very high* are considered, it is northern Tuscany that has a greater total exposure degree (Fig.11). Hence, while the idea of a north-south dualism provides a sufficient overview and explanation, regarding the assessment of territorial disparities in industrialization, the territorial disparities in terms of exposure remain associated to positional differences at local scale, and to a more intricate spatial logic, that cannot be observed in an abstract space, as the spatial characteristics of certain areas can provide more or less support to economic activities there placed.

4. Conclusion

Urban and regional economics ought to ponder about their *abstracted representation of space.* The recognition and analysis of the different territorial endowments derived from position and road-infrastructure, as well as their influence in regional disparities, are crucial factors for the effectiveness of forthcoming recovery policies. Economic studies, so far, have not taken space and spatial representation into appropriate consideration, as spatial-economic analyses are still in the shadow of applied macro and microeconomics fields, which draw attention away from the vital importance and influence of territorial features in economic efficiency. Changes in this concept in economics are dependent on the adoption of instruments that can represent territories – and the structures and networks within them – with a greater level of detail, such as Geographic Information Systems (GIS), followed by an associated development of models that incorporate economics' variables to real representations of space.

As discussed, the Territorial Exposure Index is conceived with these issues in consideration. Constructed based on the *macroareas* – a cohesive territorial unit – conceptualization, the index evaluates industrial agglomerates' distributional logics, assessing the different territorial endowments – characteristics derived from the built-structures placement – that contribute to a condition of *territorial exposure*. The concept of *exposure* evinces the support that territorial features of cohesiveness, degree of industrialization, agglomeration, and the nearness to regional *preferential routes*; provide to the economic activities there placed, in terms of allowing local and regional interindustry relationships. With this in consideration, the parametric index identifies factors of territorial sensitivity to firms' economic dynamism within an agglomerate, dependent of both position within the territory and relation to the remainder industrial spaces.

In Tuscany, spatial disparities in industrialization are associated to a north-south dualism, where septentrional Tuscany possess a greater number of larger and more cohesive industrial agglomerates, while the meridional Tuscany has a sparser industrial distribution. Still, when the parameters of industrial agglomeration and the nearness to road-infrastructures are considered, it is revealed that this dualism does not accurately reproduces the *exposure* conditions, as the highlighted territorial disparities are instead related to the urban-hinterland divide, or the presence of absence of a sufficient infrastructural support within these settings.

Challenges remain, however, in the further inclusion of economic variables to this analytic framework. Datasets that aid the assessment of industrial agglomerates' economic dynamism, such as sector, firm size, productivity or revenues, are still constrained to spatialization issues, since their survey is made at a firm level, therefore, consisting in a sensitive information about the productive activity, which can possibly lead to its identification. Research costs are also in question, since most of these databases (i.e., *ORBIS/AIDA, Registro Imprese*) are private owned and, given the scale of the analysis – regional – require substantial funds for a comprehensive data acquisition. Issues can be addressed using industrial census data as proxy parameters, at least regarding firm-size. Their adaptation to the *macroareas* concept that provides their representation as a spatial aggregate – similar to how the information is already used in economic models – thus, solving possible privacy concerns. This will allow an in-depth economic assessment and consists in the next step for this model. In this sense, it is possible to consider the Territorial Exposure Index developed until this point as the *spatial component* of a broader index that includes an *economic component* as well.

Nevertheless, even with the limitations, the overall results indicate that the proposed model and framework, based on real spatial representations, can highlight territorial disparities in the industrial agglomerates found throughout a region, as well as demonstrate how the territorial endowments presence and placement have implications on their economic dynamism, given the amount of support for the productive activities. In this regard, the model surpasses, in terms of territorial representation detail, the spatial models commonly used in Urban and Regional Economics studies.

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Image Sources

Fig.1: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.2: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.3: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.4: Regione Toscana (2019b) – Grafo Itnet – Grafo Stradario della Toscana;

Fig.6: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013; Regione Toscana (2019b) – Grafo Itnet – Grafo Stradario della Toscana;

Fig.7: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.8: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.9: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.10: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.11: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013;

Fig.12: Regione Toscana (2019a) - Edificato 2k,10k 1988-2013; Regione Toscana (2019a) – Grafo Itnet – Grafo Stradario della Toscana.

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