

Regional development and intellectual capital: Unveiling the innovation-tradition dilemma

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ABSTRACT

In the agri-food sector, intellectual capital includes innovation and tradition, which are often wrongly perceived as incompatible. The impact of intellectual capital on regional development has not been widely studied, particularly in the context of the Italian agri-food sector, which has a strong territorial heterogeneity. This paper aims to measure the impact of intellectual capital and know-how on regional development in the agricultural sector using a nonparametric efficiency methodology applied to a unique geographic area-based dataset. The study finds that innovation, measured by patents, has a better impact on efficiency than the relational component, which has an inverted U-shaped effect.

1. Introduction

Rural development is becoming increasingly important in the globalized scenario [1]. The new urban flows and the growing demand for a new post-covid normality place the relationship between economic development and local geography within a context of strong international competitiveness. The sector that retains the strongest economic relationship with the surrounding territory is certainly the agri-food sector.

In this regard, intellectual capital represents the driving force for regional development in rural zones. Its influences are observed via its three pillars: human capital, relational capital, and structural capital. Intellectual capital, across both rural and urban areas, encompasses two fundamental aspects: innovation and tradition. Intellectual capital is most decidedly exhibited in its fullest effect in the agri-food sector. Yet, it is customary to believe (wrongly) that the agri-food sector is characterized by a low capacity for research, development, and innovation [2]. The evidence is that positive technology and innovation shocks to agriculture, via human capital, have played a key role in igniting a transition from traditional practices to modern practices that have contributed to long-term economic growth in almost all countries. In contrast, human capital has been unable to enhance the tradition of know-how in the agricultural sector that, for decades (if not centuries), has been handed down as wisdom and knowledge.

In Italy, the very long centuries-old tradition of procedures and

methods of processing agricultural products is accompanied by a very strong territorial heterogeneity, which is reflected in a great number of territorial locales. The concept of heterogeneity also concerns the significant differentials between urban and rural areas [3]. The geographic area concept, including both Urban Areas and Rural Areas (URA), adopted in this paper captures these all-important policy and investment differentials.¹ Furthermore, the production of patents in the Italian agri-food sector is also characterized by a great dynamism in terms of advancements in scientific-technological research. Therefore, the aim of this work is to measure the impact of intellectual capital and know-how on regional development in the agricultural sector using an original and innovative approach. We apply a nonparametric efficiency methodology, without any a priori assumption, to a unique geographic area-based dataset. This approach makes the model extremely flexible and suitable for analyzing this type of data and relationships.

The outline of the paper is as follows. First, the literature section reviews the concept of intellectual capital in the agri-food system and establishes the hypothesis of the work. The second section details the nonparametric efficiency methodology that is applied at the regional level of data. The third section describes the data and the descriptive statistics used in the analysis. The fourth section describes the empirical results. First, evidence is provided to show how the patent density and consortium density both contribute to improved efficiency in the agri-food industry. Second, the extent to which this improvement could be correlated with some intrinsic characteristics of the regional areas

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¹ URA includes a worldwide coverage of urban areas and, in the meantime, regionalized boundaries (states, departments, provinces, prefectures ...) of the areas which are outside of the highest concentrations of inhabitants.

(geographical, economical or size parameters) is examined. The fifth section discusses the impact of these findings on policy implications, and the last section includes the conclusion.

2. Literature review

The vital role of agriculture is unquestionable, due to the human welfare reliance on agricultural production, in terms of the amount and stability of its outputs [4], as well as the tight boundary that links this sector to the environment. As agri-food firms are highly connected with the local territory they are taking a more integrated approach to dealing with regional and local realities than in the past. For example, the liberalization of global trading in food products is hastening a resurgence of agricultural products identified by named regional and local qualities.

2.1. The agri-food system

The rural economist Malassis long ago suggested the concept of agri-food systems, and his perspective has mainly been used in analyses conducted at the global scale [5,6]. Such studies sought to qualify various kinds of agri-food models into a taxonomy [7]. In this framework, it is critical for each territory to generate, replicate, and share its own knowledge. This is true whether such knowledge is comprised of traditional or scientific-technical information, or a combination of the two, designed to ensure cultural sustainability [8]. The local production structure is made up of networks of small and medium businesses and agricultural farms that specialize in a narrow agri-food niche not limited to a specific region. They encompass a wide range of interdependent relationships, both transnational and non-market in nature. This network creates economic value outside of the related industries and serves as a social space for knowledge diffusion and creativity [9].

2.2. The intellectual capital in the agri-food system

Intellectual capital is a key measure for assessing the clash between tradition and innovation in the agricultural sector. No other industry sector exhibits the level of prominent coexistence between these two avenues for conveying information across generations. The studies in this field are extremely fascinating, and the research trend is substantial and enduring (Chambers [10], and Agrawal [11]), constantly brings forth new insights and conceptualizations [12]. In this regard, intellectual capital represents the concept that encompasses the full value of knowledge, both traditional and innovative, that impact the development of a given territory, even in the agri-food sector. According to the ecosystem approach, creating new value is represented by the sharing of knowledge both inside and outside the organization [13]. In this way, intellectual capital is a decisive factor for the economic development of a territory. This perspective combines human, relational and structural capital into a new vision that considers the social aspect of IC [14]. The literature therefore defines intellectual capital in a relatively strict form. In this paper, we seek to identify the most appropriate definitions according to the different pillars: human, relational, and structural capital.

2.3. Human capital

In agriculture, human capital has always been a decisive factor for development. Farmers need to rely on their peers to master practices and to implement technical changes, according to their norms [15]. Thus, the importance of professional dialogues among peers to understand the logics of action [16] and to more precisely understand the dynamics of technical changes in agricultural practice has been highlighted [17]. Also, the social network analysis approach appeared promising to show the role of dialogic professional ties between peers in mastering technical changes [18].

2.4. Structural capital

As far as structural capital is concerned, literature has always used patents to reflect this type of knowledge [19]. Patents are part of the firm's intellectual capital observed in the form of organisational capital [20], in addition to other sources of intellectual capital, like human capital and relationship capital, and can supplement other kinds of organisational capital, such as databases and organisational processes. This holds true, despite the agri-food industry as usually considered a low-tech industry sector [21]. This can be attributed to the agri-food industry enjoying the benefits derived from patents born in other industry sectors [22]. In this light, innovation and patents in the agri-food sector arise mainly from internal and external relations within the company, in a systemic logic, and not only in the R&D departments of private companies.

The external sources of knowledge agri-food companies are more decisive for innovation in the agri-food sector as a whole. This reveals that the sector lends itself well as a case study of territorial versus widespread knowledge. The results will generate insights into the relationships and connections that exist between businesses, between businesses and their territory and institutions, and within rural and non-rural areas. Furthermore, it is well known that innovations in the agri-food field are affected by patents deriving from multiple scientific and technological sectors, like pharmaceuticals, chemicals and agriculture, machine tools and the electrical product sectors [23], nanotechnology [24], or biotechnology [25]. Despite the heavy reliance of agri-food firms on previous scientific and technological knowledge, few papers have empirically analyzed these science–technology linkages.

2.5. Relational capital

In addition to human and structural capital, the remaining pillar to be explored in terms of scientific literature is relational capital. An interesting experience of relational capital can be identified in Protected Denomination of Origin (PDO) products, especially with a view to developing a complex of relationships and knowledge [26,27]. Such labels represent a great opportunity to certify a system of relationships, techniques, and knowledge of a specific territory. The "culture of quality" concept is widely discussed in agri-food field. The generation of dynamics of territorial cohesion and involvement around the adopted quality model has been excellently encapsulated in this notion [8].

Indeed, this focus on relational capital has fostered the development of a sense of belonging to the region [28], which truly is a critical component in the development of long-term territorial continuity policies. Todeva & Knoke [29] posit that the exclusive use of a geographical name necessitates the formation of a producer collective. To control the use of the appellation, for example, wine makers must create a producer group. Local items are considered cheap goods produced within a "local manufacturing environment" and are eligible for a PDO. These reasons lead us to consider the number of quality labels for both rural or urban areas, to be used as a proxy of human and relational capital that contains the know-how of the associated territory.

Indeed, there are very few empirical works that have measured the impact of human capital on territorial development in the agri-food sector. This is especially true when involving measures that are not typical of this sector, such as patents and knowledge relations. This paper intends to bridge this gap, to measure the pillar of intellectual capital with the greatest impact on rural and urban development, replying to this research question.

RQ1 Can we measure, in the agri-food sector, the effect of intellectual capital proxied by the local inventive capacity and presence of PDO certification on the regional development?

This analysis is particularly interesting in the Italian context, which has always been marked by strong economic and geographical

disparities. In fact, the significant infrastructural gap causes Italy to function at two different speeds. As illustrated by various studies, the problem is not only the disparity between the north and the south. Heterogeneity is also present between the central regions and the periphery. This leads us to our second question.

RQ2 Is the effect of this intellectual capital dependent on local heterogeneities (urban areas vs rural areas, northern areas versus southern areas, size of the areas)?

The research design of this study and the data used (URA delineation) with a nonparametric approach, represent an effective way to test the impact of intellectual capital in a context full of heterogeneity. In fact, classical quantitative methods often fail to address these issues. In the following section we discuss the efficiency and productivity methodology applied.

2.6. Research design

Efficiency in agriculture is heavily discussed in the natural resource management literature [27,30]. An important aspect of this research is undoubtedly to examine the ability of technological innovation and intellectual capital to impact the production process, even if it is not strictly a production process. Therefore, the most suitable methodology for verifying the research hypotheses of this work is the conditional efficiency approach.

Conditional efficiency is a methodology used in data envelopment analysis (DEA) to assess the efficiency of decision-making units (DMUs). In our case, such units are defined as Urban and Rural areas, collated by taking into account environmental or other external factors that may affect their performance. The conditional efficiency approach allows for the estimation of the impact of external factors on the efficiency of DMUs, which can be useful in policy-making and decision-making contexts. It also allows for the identification of factors that may be contributing to inefficiency, which can guide interventions aimed at improving performance.

Starting with a version of the models used by Cazals et al. [31] and Daraio & Simar [32], we consider a production technology where the activity of the production units is characterized by a set of inputs $X \in \mathbb{R}_+^p$ used to produce a set of outputs $Y \in \mathbb{R}_+^q$ and $Z \in \mathbb{R}_+^d$, generic vector of environmental variables. We can define the attainable set $\Psi^Z \subset \mathbb{R}_+^{p+q}$ as the support of the conditional probability:

$$H_{X,Y|Z}(x, y|z) = \text{Prob}(X \leq x, Y \geq y|Z = z)$$

Accordingly, the conditional output-oriented technical efficiency of a production plan $(x; y) \in \Psi^Z$, facing conditions z , is defined in Ref. [32] as:

$$\lambda(x, y|z) = \sup\{\lambda | (x, \lambda y) \in \Psi^Z\} = \sup\{\lambda | S_{Y|X,Z}(\lambda y|x, z) > 0\}$$

where $S_{X,Y|Z}(x, y|z) = \text{Prob}(Y \geq y|X \leq x, Z = z)$.

Assuming that the true attainable sets are convex and under free disposability of inputs and outputs, the conditional DEA estimators, facing the conditions $Z = z$, can be written as [33]:

$$\hat{\Psi}_t^Z \text{DEA} = \left\{ (x, y) \in \mathbb{R}_+^p \times \mathbb{R}_+^q \mid \begin{array}{l} y \leq \sum_{j \in J(z,t)} \gamma_j y_j; \sum_{j \in J(z,t)} \gamma_j x_j \\ \gamma \geq 0 \text{ s.t.} \\ \sum_{j \in J(z,t)} \gamma_j = 1 \end{array} \right\}$$

The choice of appropriate bandwidth selection is the focus of Daraio & Simar [32,34] and Bădin et al. [35] studies. They are determined following the procedure adopted in Hall et al. [36] and in Li & Racine [37].

The effects of conditioning variables on the boundary and on the

distribution of the inefficiencies can be identified using the approach developed by Bădin et al. [38]. The effect on the boundary can be detected by assessing the ratios between conditional to unconditional efficiency measures, $(\lambda(x, y))$.

The ratio to be analyzed is:

$$R_o(x, y|z) = \frac{\lambda(x, y|z)}{\lambda(x, y)}$$

The study of this ratio is essential when measuring the impact of conditioning variables on efficiency. Our output-oriented approach favors using DMUs that maximize outputs. Observing an increasing trend of this ratio relative to the patent variable implies that patents have a positive impact on efficiency. Conversely, a negative trend means that patents have a negative impact on efficiency. Other conditioning variables, i.e. the consortia, can be interpreted in the same manner. This empirical result is extremely important because we do not impose the a priori positive or negative impacts of these variables. Instead, we verify such impacts ex ante by studying the trend of Ro on the conditioning variables.

To limit the problem of the “curse of dimensionality”, our DEA conditional efficiency approach considers more than the traditional input and output of the production function. We also focus on two environmental variables: the density of patents in agricultural field and density of PDO consorti. Table 1 explains the variables considered in our DEA conditional efficiency approach.

The input variable Labour is represented by the number of employees, while Material Asset is used as proxy for the capital variable. Added Value represents the output variable. Regarding external variables, we adopt density of agri-food patents (structural capital) and density of PDO certification (human and relational capital) as proxies of intellectual capital. A schematic representation of the analysis is shown in Fig. 1).

3. Materials

3.1. Data collection

The geographical units of our analysis are the Urban and Rural Areas (URA) boundaries (Villard and co. [44]). For Urban Areas, we use the definition of the Functional Urban Areas (FUA) built by OCDE following a core analysis by population density with the addition of dependant commuting data. New entities, Rural Areas, have been built outside these Urban Areas. Such areas have been created to fill portions of geographical space which are located outside Urban Areas. Therefore, the limits of the Rural Areas are designed following the “first-order administrative boundaries and polygons” for countries using a regional layer published by Natural Earth, i.e. NUTS3 regions in Europe (and Provinces in Italy). An example of Urban and Rural Areas in southern Italy is shown in Fig. 2, where ITP45 NUTS3 region is split in two parts: Lecce Urban Area and Lecce Rural Area.

Following the classification proposed by OECD for FUA, urban areas are classified based on their population, and a new classification has been established for Rural Areas. Our complete final classification is:

- Very small (rural areas below 50 000; all urban areas with a population below 50 000 have been withdrawn)
- Small (urban or rural population between 50 000 and 100 000)
- Medium-sized (urban or rural areas with population between 100 000 and 250 000)

Table 1

Variables used in efficiency analysis.

Input	Output	Z variables
Number of employees	Added value	Density of agri-food Patents
Material Asset		Density of PDO certification

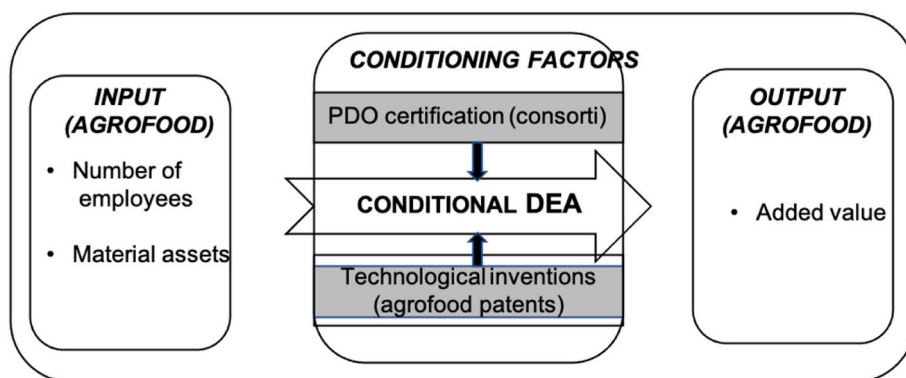


Fig. 1. – Schematic view of the efficiency analysis.

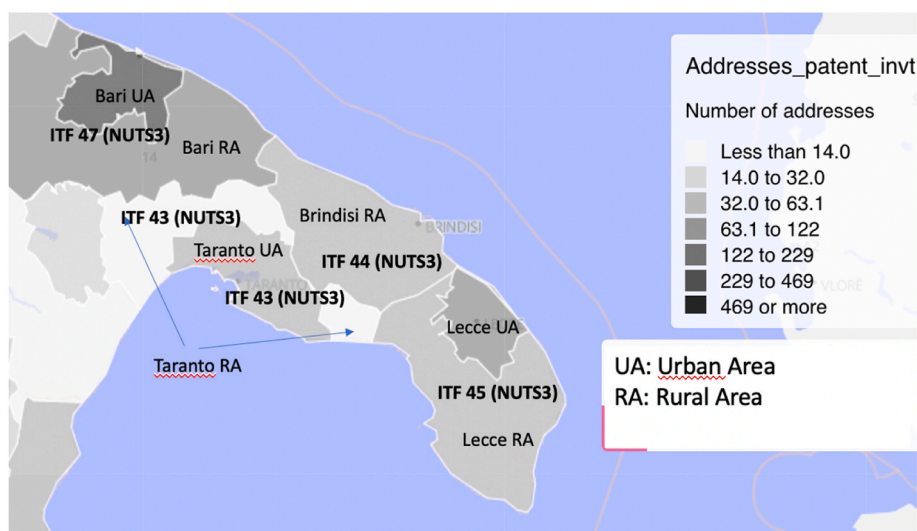


Fig. 2. – Example of the delineation between Urban and Rural Areas in Italian NUTS3 regions.

- Metropolitan (urban or rural areas with population between 250 000 and 1.5 million)
- Large (urban or rural areas: with population above 1.5 million)

Italy includes 153 URAs: 66 (43 %) are in northern Italy, 55 (36 %) in southern Italy, and 32 (21 %) in central Italy. Almost half of the Italian URAs are Medium-sized Rural areas or smaller rural areas (this share peaks at 60 % and 51 % in central and southern Italy). Further, 40 % of Italian URAs are Medium-sized Urban areas or Small Urban Areas (this share is 47 % in northern Italy and close to 35 % in the south and central Italy). Large Metropolitan Areas and Metropolitan areas represent 6.5 % of Italian URAs while the share of Rural areas is 5 %. All addresses used for this research have been first geocoded and then allocated to URAs using the geospatial processing facilities powered by the open access Cortext Manager online platform (<https://managerv2.cortext.net>). The overall dataset we use has been built by crossing data from the different databases listed below.

3.2. Consortia

The list of the consortia originates from the Italian Ministry of Agricultural, Food and Forestry Policies. The allocation of the protection consortia and the companies belonging to them to URAs was done based on the addresses of the production sites. Therefore, each URA was assigned a number of PDO certifications, based on the consortia presence.

3.3. Patents

For the selection of agri-food patents, we follow the approach proposed by the Australian IP office to analyze the Australian food industry that combines International Patent Classification (IPC) searches and keyword searches in titles and abstracts (the detailed list of IPC codes and lexical terms are given in Ref. [39] and listed in Annexe1). We use the Risis Patent Database, an enriched and simplified version of the Patstat database (version 2017), for all the agri-food priority patents applied between 2010 and 2014 with at least one inventor located in Italy. While 656 distinct priority patent applications were retrieved (which corresponds to 524 patents when summing the total fractional contribution of Italian inventors²), this corresponds to 1,85 % of the overall number of priority patent applications involving Italian inventors). Inventors' addresses were geocoded and allocated to Italian URAs. Therefore, for each URA, the number of agricultural innovation patents involving an inventor located in that specific geographical area was calculated.

3.4. Economic data

Finally, the agri-food economic strength of each URA was calculated by aggregating the agricultural sector companies with registered offices

² The difference relies to the presence of inventors located outside Italy among the patents with inventors based in Italy.

in the geographical area of reference. We collect data from companies belonging to sector 1 and 10 of the NACE classification. Data regarding balance sheet and financial values of all companies have been extracted from AIDA, a database that contains comprehensive information about companies in Italy, released by Bureau Van Dijk. From the latter, the number of employees, added value, revenues, and total assets, have been extracted for each company belonging to each URA for the 2015–2020 time period.

In Table 2 we display the data accounting for the agri-food activity for each URA type. It is interesting to note that both Urban and Rural areas are relatively committed in agri-food innovation. Almost all areas (178 among 184) report the presence of agri-food companies and four out of ten of these areas are Urban ones. Moreover, between 60 % and 70 % of the Italian URAs declare that they rely on their local intellectual capital to innovate or certificate its local products. Technological based innovation is more often found in Urban areas while consortia are located first in Rural areas. However, approximately half of the URAs committed in the agri-food sector combine both technology and certification activities.

3.5. Summary statistics

The geographical distribution of our environmental variables, patent density, and consortia density among rural and non-rural areas in Italy are all shown in Figs. 3 and 4

The agri-food patents follow the distribution of innovation in Italy (see Fig. 3). Higher densities are concentrated in the north, with few values exist in the center (Lazio) and a low level in the south. It is interesting to relate this with the geographical diffusion of consortia (Fig. 4), because the two variables are related but also quite different. Both represent a signal of innovation and proof of a local and specific economic activity, but the rationale for each is quite different.

Indeed, we can see that the peripheral areas (Sardinia, Campania, Sicily) have positive (grey) values in a veritable “sea” of white. Areas with large numbers of consortia are concentrated in the north, but the geographical disparity with the south has greatly diminished. It is assumed that the quality of agri-food products in Italy is equally distributed between north and south. This figure demonstrates that the ability to have a recognized and protected designation product is easier in the north than in the south. This illustrates a serious organizational and territorial development problem in the south.

The distributions of patents and consortia densities, measured as the number of patents or consortia over the number of inhabitants (x 1M)

across Italian URAs, are very skewed. The distribution of URAs with a patent density above the median value is unevenly distributed in Italy, as evidenced by 79 % of URAs in northern Italy having a patent density above the median value. In central and southern Italy, respectively, 44 % and 20 % of the URAs are above the median value of the patent activity. Similarly, northern Italy concentrates a high share of URAs (73 %) with a consortia density above the median value. This share is equal to 41 % in central Italy and to 30 % in southern Italy. Lastly, 30 % (46 URAs) of the Italian URAs show both a patent density and consortia density above medians. Most of them (83 %) are in northern Italy and are Medium-sized and Small Urban and Rural Areas.

4. Results

In this section, we detail the empirical findings from our efficiency analysis of rural and non-rural areas, which is complemented by insights derived from our cluster analysis. Through rigorous methodologies, we have identified distinct patterns and efficiencies across these regions. Our comparative discussion elucidates the relationships and discrepancies found within and between clusters. This multifaceted exploration provides a deeper understanding of regional characteristics and their implications.

4.1. The conditional efficiency: effects of patent density and consortia density

First, we investigated if there is any effect of consortia and patent densities on the level of efficiency. The full frontier ratio shown in Fig. 5, is illustrated from a marginal point of view. It shows a strong and clear positive effect of patent density on the shape of the frontier. This empirical evidence demonstrates that the capacity to conduct inventive activities does contribute to an overall increase of the production function in the agri-food system in the area.

Concerning the effect of the consortia density, the result exhibits a nonlinear effect. Initially, a positive effect on the efficiency can be observed across the small to medium levels of consortia intensity (see Fig. 6). However, this is followed by a negative effect. This implies that the consortia presence initially exhibits a strong effect for small number of consortia per inhabitants. Eventually, a “saturation effect” occurs with a light negative effect on efficiency associated with the number of consortia. A hypothesis could be linked to the heterogeneity of the Italian context considering that some areas are more able than others to benefit of the consortia presence.

Table 2
– Agri-food activity in Italian URAs.

URA type	Number of URA	Number of URA specialised in agri-food ^b	Number of URA with agri-food firms	Number of URA with consorti	Number of URA with patents	Number of agri-food firms	Number of consorti	Number of patents ^a
Large metropolitan area	4	0	4	4	4	2560	65	98
Metropolitan area	7	4	7	5	7	835	18	61
Medium-sized urban area	21	8	21	12	18	1848	127	103
Small urban area	42	17	41	20	29	1320	38	107
Rural area	8	3	8	7	6	1368	106	43
Medium-sized rural area	50	18	50	38	37	4352	198	68
Small rural area	47	16	44	30	24	1631	137	43
Very small rural area	5		3	0	0	32	0	0
Total	184	66	178	116	125	13946	689	524
Share of URA	100.0 %	35.9 %	96.7 %	63.0 %	67.9 %			
Urban Areas	40.2 %	43.9 %	41.0 %	35.3 %	46.4 %	47.1 %	36.0 %	70.6 %
Rural Areas	59.8 %	56.1 %	59.0 %	64.7 %	53.6 %	52.9 %	64.0 %	29.4 %

^a fractional counting of Italian inventors.

^b specialisation in agri-food is measured based on patent data.

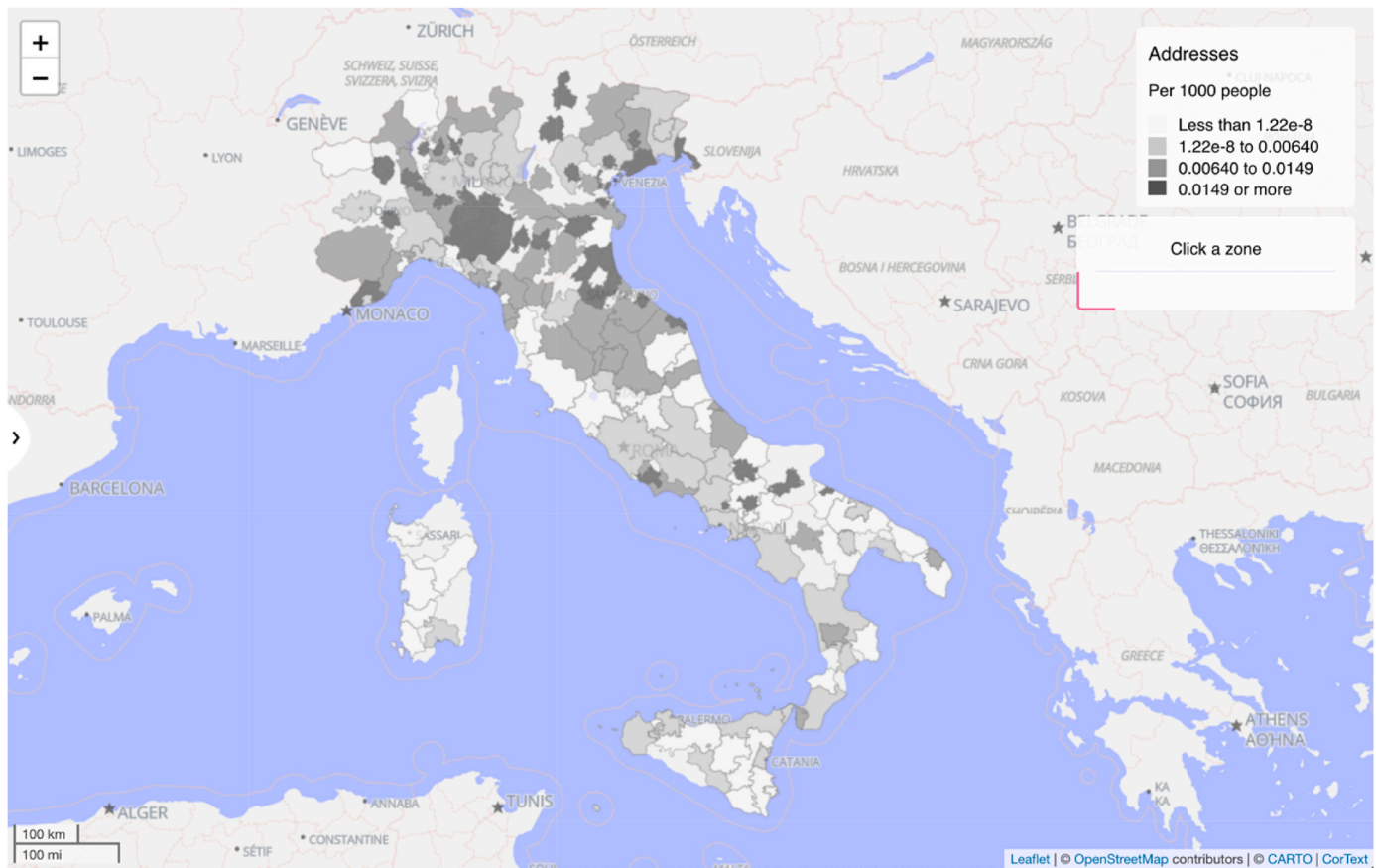


Fig. 3. – Density of the patenting activity in Italian URAs.

This section provides evidence that the local innovative capacities and product certification can positively affect the local agri-food economy and has answered our first research question. Considering that the agri-food system is linked to the development of technologies and an alternative more traditional model, we demonstrate that each model is beneficial for the sector economic productivity (with a higher positive impact for the technology). Yet, to get a more precise view of the results, we plot the level of conditional efficiency for each Italian URA as a function of its patent density (x-axis) and its consortium density (y-axis) (see Fig. 7). The level of conditional efficiency of the URA is indicated by a colour code from red (average conditional efficiency) to grey (moderate efficiency) and green (high efficiency). The dimension of each element on the graph is given by the number of consorted companies belonging to each URA: this gives a dimension of the size and vocation of each area.

The graph is very instructive. It reveals that increasing either the patent density or the consortia density tends to increase the conditional efficiency. However, we observe a significant synergy effect between the two parameters: the highest efficiencies are obtained when an URA combines both a high patent density and a high consortia density (green and dark green dots in the upper right-hand side of the graph). When the two types of capital, namely structural capital and network capital, are available in the same area, the firms in that territory have the capacity to increase the efficiency of the production function of the local agri-food system. Such a combined efficiency also seems to be more intense in areas where the consortia are rather large, i.e. include a high number of consorted firms. This is the case in the areas of Parma (both rural and urban parts of the province) or Piacenza in Emilia-Romagna, Lecco in Lombardia or Cuneo. All these areas are in the north of Italy. They combine a capacity for technological innovation with the ability to organise the network to promote good products through DOP

certification.

Of course, there are some outliers: Naples or Palermo, both in southern Italy, show a very high conditional efficiency without a high density of patents or consortia.

4.2. Cluster analysis insight

In order to assess whether we could further correlate any URA-specific characteristics with the level of conditional efficiency, we carry out a final analysis by first carrying out a hierarchical clustering (Ward linkages) of the URAs. We take into account their attributes: economic variables, geographical variables and agri-food intellectual capital, and then analyze whether significant differences in the level of conditional efficiency can be found between the clusters. The results of the analysis, considering all the variables available, make it possible to identify six clusters that capture well the heterogeneity between clusters and the homogeneity within clusters (Table 3, Fig. 8). These clusters are very heterogeneous in terms of size, ranging from a very small cluster with only 2 URAs (cluster_1) to a very large cluster containing almost half of the sample with 69 URAs (cluster_6). The composition of the six clusters, the mean values of the variables related to the local economy and the agri-food activity of the URAs are shown in Table 4.

To understand the impact of clustering in explaining efficiency in each cluster, we also measure the mean and variance of conditional efficiency for each cluster. The results appear in Table 5

Interestingly, we found similarities but also differences in the mean conditional efficiency between the different clusters. Cluster_1 and Cluster_2, which together represent 7 % of the URAs, contain a limited number of URAs with a very high conditional efficiency ($\text{mean} \geq 0.88$). These URAs are mostly located in rural areas of Northern Italy (in particular in the Parma region, the two top URAs, or in other regions of

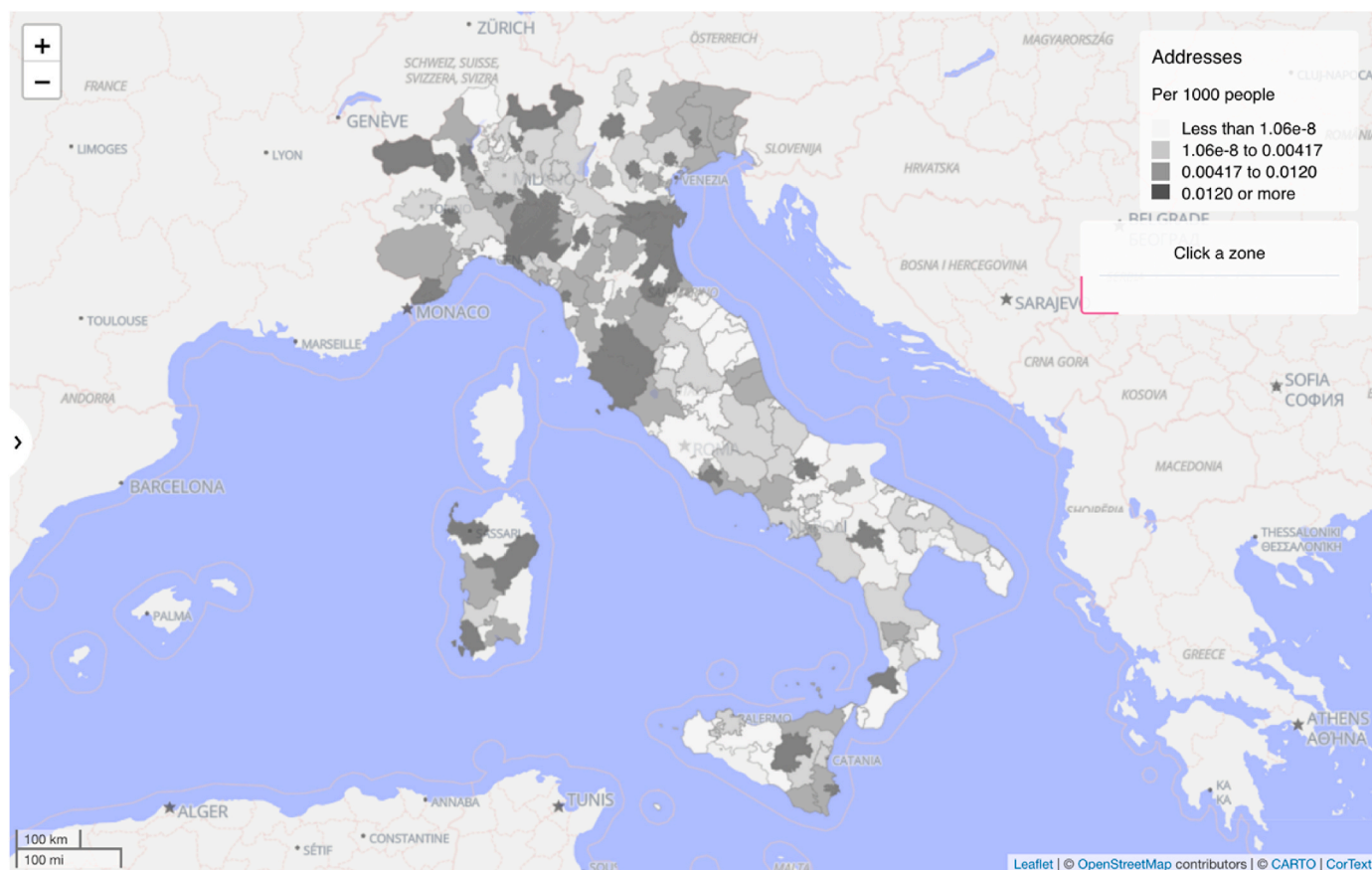


Fig. 4. – Density of the consortia in Italian URAs.

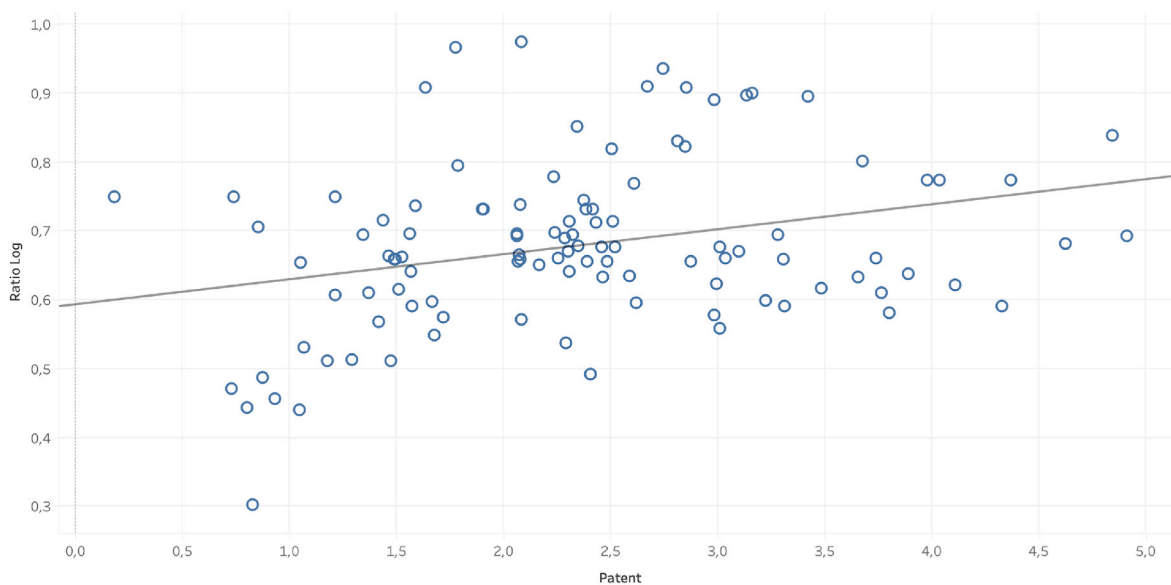


Fig. 5. – Evolution of the DEA ratios with the patent density in Italian URAs.

Emilia Romagna such as Modena or Piacenza, all of them with very well-known traditional products, but also two Sardinian URAs). These are rather small URAs, with a low average population but a large and efficient agri-food sector. These URAs are also characterised by a high number of large consortia (number of consorted firms/number of consortia) and a high density of consortia. At the same time, innovative activity in the agri-food sector is quite significant. The density of patents

in the agri-food sector, based on local knowledge, exceeds the average density in the other clusters. These URAs are also quite specialised in agrofood innovation compared to the Italian regional average.

In clusters 3, 4, and 5, the average conditional efficiency is between 0.76 and 0.81. These URAs perform quite well in using traditional and innovative activities to improve the efficiency of their local agri-food economy. A comparison between cluster 2 and cluster 3 is very

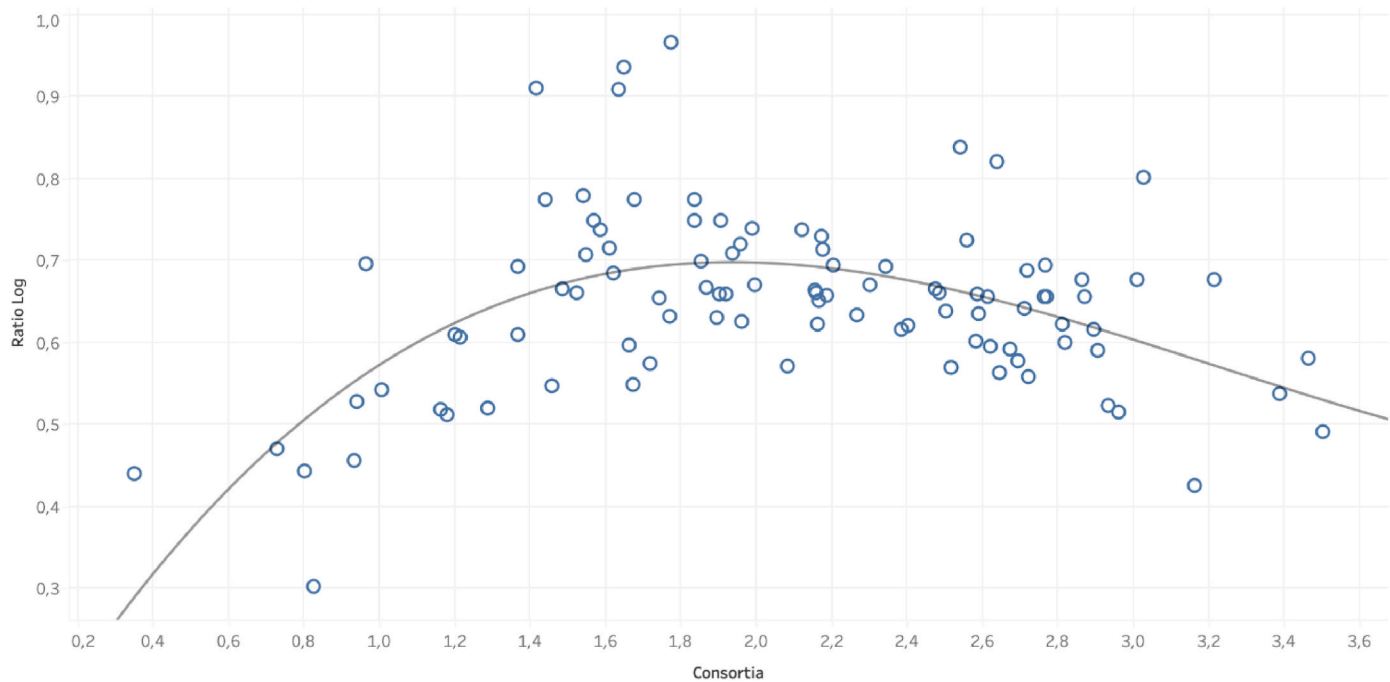


Fig. 6. – Evolution of the DEA ratios with the consortium density in Italian URAs.

revealing. Cluster 3 includes URAs with geographical characteristics close to those observed in Cluster 2 (more northern URAs, similar size), with a slightly less developed agri-food economy. The URAs are mainly located in Emilia-Romagna (8 URAs), Venitia (5 URAs) and Lombardia and Toscana.

The real difference between Cluster 2 and Cluster 3 is not only the density and size of the PDO consortia, but also the innovation intensity. In Cluster 3, the average number of consortia per URA is 3.5 less than in Cluster 2 and the consortia are twice as small. Similarly, URAs in cluster 3 are half as inventive in the agri-food sector as URAs in cluster 2. These zones have developed innovation activities but have not focused on the agri-food sector as URAs in cluster 2. The comparison between Cluster 2 and Cluster 5 is also very interesting. The URAs in the two clusters are similar in size, but more rural and less concentrated in northern Italy in Cluster 5. Despite a high level of PDO activity in these areas (quite similar to Cluster 2), these URAs make less use of their intellectual capital to improve their agri-food sector performance. This could be related to the smaller size of their agri-food economy, but also to their poor performance in agri-food innovation. Compared to cluster 3 and cluster 5 with similar conditional efficiency, cluster 4 is more urban and contains more southern URAs (Lombardie (5 URAs), Toscane (3 URAs), but also from Campania (2), Puglia (2), Sardinia (2)). In these areas, the agri-food economy is not very developed, there are PDO certification activities and agri-food innovation, but they remain moderate.

Finally, cluster 6, the largest cluster (46 % of the URs), reveals a number of URAs have a rather low conditional efficiency (mean: 0.71). This cluster is composed of larger areas with low or very low agri-food economic activity, very low PDO activity, moderate agri-patent activity, but not specialised in agri-food. This cluster is quite heterogeneous, including large areas. These are mainly located in the centre of the nation, as well as small urban areas from the centre and south (Puglia, Calabria, Sicily, Toscana). However, this includes large cities such as Turin or Milan, which show a rather high range of conditional efficiency. There are also some well-performing areas close to well-known urban centres, such as Roma and its rural area, Bologna and its rural area or Como and its rural area.

5. Discussion and policy implication

These results support our previous assumptions. The combination of both traditional and innovative activities in the agri-food sector allows territories to obtain the highest productive efficiency associated with innovation. Focusing on only one aspect of innovation makes it possible to benefit from the overall economic development of the agri-food sector, but with lower efficiency. The ability to benefit from the synergy effect of traditional and innovative activities in the agri-food sector allows some regions to perform extremely well in terms of the productivity of their agri-food system. These regions are located in northern Italy, primarily in Emilia-Romagna. Neither their type (rural or urban) nor their size really matters. They benefit from a regional environment in which both activities are promoted and mastered thanks to adapted human, relational and structural capital.

We also find a positive effect of the size of the agri-food sector on the local ability to benefit from PDO certification and innovation to increase the economic efficiency of the agri-food sector. The URAs with the largest agri-food sectors perform better. They are often specialised in agri-food production. The effects of agri-food patent density and consortium density also help to explain the results of the clustering analyses. URAs with higher patent densities perform better than URAs with low inventive activity. Consortium density also plays a role, but not a simple linear one. This has already been shown in the first part of the results section (an inverted U-shaped relationship between conditional efficiency and consortium density was observed).

The analysis of the characteristics of the URAs in the different clusters suggests that the size of the consortia also plays a key role. URAs that host large consortia, i.e. consortia that include many enterprises, perform better than URAs where consortia include on average only one or two enterprises. Therefore, it seems that both the density and the size of consortia should both be considered to fully benefit from the presence of local PDO certification. The multiplication of the presence of small consortia in a given territory appears to be detrimental to regional efficiency, while larger and fewer consortia appear to be a better strategy for promoting local economic development. This is an important finding of this work.

From a geographical point of view, we confirm that, even in the agri-

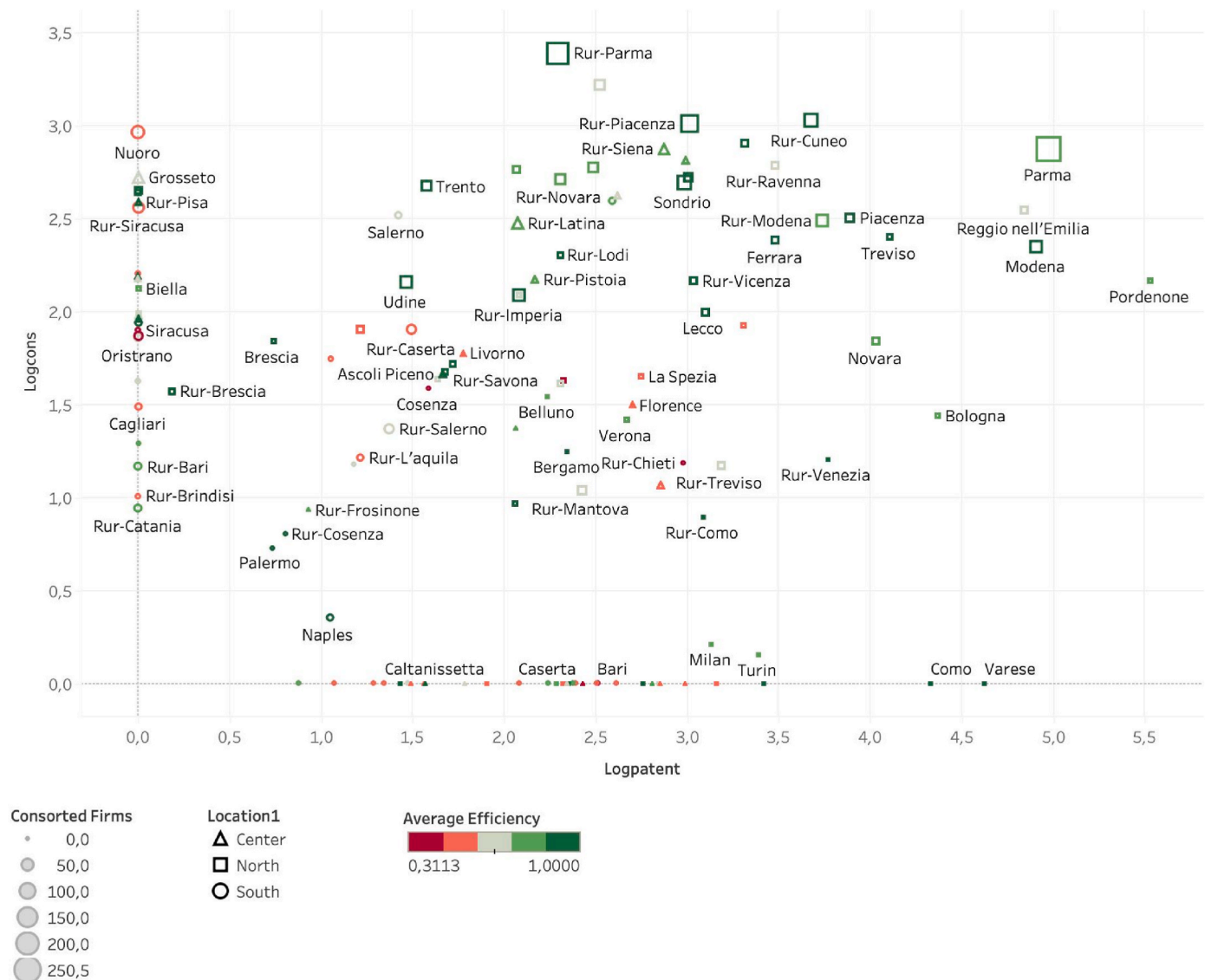


Fig. 7. – Consortium density (logcons), patent density (logpatent) and conditional efficiency in Italian URAs (rur-: Rural; else Urban).

food sector, northern (or central) Italy often performs better on average than southern Italy. The northern regions tend to contain medium-sized rural or urban areas with a very dynamic agri-food sectors, thanks to their capacity to maintain both traditional and innovative activities in an efficient way. Specifically, these territories exploit specialisation in the development of agri-food innovation and the presence of efficient and large PDO certification consortia. Interestingly, some southern areas have also been able to develop such local skills. In particular, investing in innovation helps reduce regional disparities, even in those areas characterized by a strong traditional heritage.

These findings have strong policy implications. In fact, it is common to find strong territorial specializations in Italy, where regions with traditional background are also regions that are innovative. Development, on the other hand, benefits most when both components interact in a synergistic manner. These findings reveal the need to design innovative development policies that precisely focus on the so-called rural or internal Italian areas. They should be designed to reduce geographical disparities, promote integration between territories, and promote the durability of the traditional heritage. In fact, without economic progression, we also risk losing historical tradition.

6. Conclusion

There is a misconception that the agri-food industry has a low capacity for research, development, and innovation. This notion is unfounded, as this industry has a long tradition of know-how that has been passed down for centuries and has informed the development of technological innovation. Despite the significance of intellectual capital in rural development, there is a paucity of works that have quantitatively measured its impact. Simultaneously, intellectual capital is increasingly recognized as a critical element in the development of rural areas, especially in the current globalized scenario. Urban population flows and growing demands for a post-COVID normality have heightened the need for economic development that corresponds to the agri-food territory to which agri-food businesses belong.

Within this context, intellectual capital, which is comprised of human capital, relational capital, and structural capital, is the driving force for rural development [40,41]. Therefore, intellectual capital has two fundamental aspects that relate to rural and urban areas: tradition and innovation. In the agri-food sector, both aspects are crucial in fully realizing the impact of intellectual capital. The Italian context is particularly interesting in this regard, as its centuries-old tradition of agricultural methods and procedures is accompanied by a great

Table 3

– Geographical distribution of URAs in the clusters.

Cluster_id	clus_1	clus_2	clus_3	clus_4	clus_5	clus_6	Total
Number of URA	2	9	27	30	13	69	150
Share of URA	1,3 %	6,0 %	18,0 %	20,0 %	8,7 %	46,0 %	100,0 %
Very large or large URA (share)	0,0 %	11,1 %	7,4 %	13,3 %	7,7 %	14,5 %	12,0 %
Medium-sized URA (share)	50,0 %	44,4 %	44,4 %	30,0 %	46,2 %	47,8 %	43,3 %
Small or very small URA (share)	50,0 %	44,4 %	48,1 %	56,7 %	46,2 %	37,7 %	44,7 %
North (share)	100,0 %	77,8 %	70,4 %	43,3 %	46,2 %	44,9 %	52,0 %
Center (share)	0,0 %	0,0 %	18,5 %	16,7 %	23,1 %	20,3 %	18,0 %
South (share)	0,0 %	22,2 %	11,1 %	40,0 %	30,8 %	34,8 %	30,0 %
Rural (share)	50,0 %	77,8 %	74,1 %	56,7 %	92,3 %	42,0 %	57,3 %
Urban (share)	50,0 %	22,2 %	25,9 %	43,3 %	7,7 %	58,0 %	42,7 %

territorial heterogeneity, which reflects the diverse regional specificities [42]. This heterogeneity also extends to the profound divergences between urban and rural areas. The adopted geographic area concept captures the crucial policy and investment divergences, overcoming the problem of the distinction between urban and rural areas [43]. The Italian agri-food sector is also notable for its dynamism in

scientific-technological research, which is evidenced by the production of patents.

The objective of this study is to measure the impact of intellectual capital and know-how on rural development in the agricultural sector through a novel approach. The methodology utilized in this study is a nonparametric efficiency technique that is particularly suitable for geographic area-based data relationships, providing an extremely flexible model without any a priori assumptions. The findings of our empirical analysis emphasize the crucial role of intellectual capital in enhancing the efficiency of economic and agricultural activities within territories.

Our findings indicate that, within the realm of intellectual capital, the innovative aspect represented by patents has a more pronounced influence on efficiency compared to the relational component. Further, the number of consortia, indicating the capacity to build a system and preserve traditions, also exerts a positive impact. However, it displays typical traits of relational capital, initially showing a strong positive effect that eventually diminishes into a negative inverted U-shaped pattern. This suggests that an excessive concentration of various, often small consortia in the same area hinders efficiency development and leads to negative consequences.

Conversely, innovation always yields beneficial results, as patents consistently contribute positively to efficiency at any level. Furthermore, the study reveals that the coexistence of both dimensions of intellectual capital in a territory creates a synergy, amplifying the potential effects on agri-food system efficiency. This outcome holds significant importance when devising policy measures for the regional development of such areas. While promoting traditional excellent agri-food products in rural and southern Italy remains essential, regional policies must also prioritize the development of regional R&D capabilities to foster local technological innovations as a primary objective.

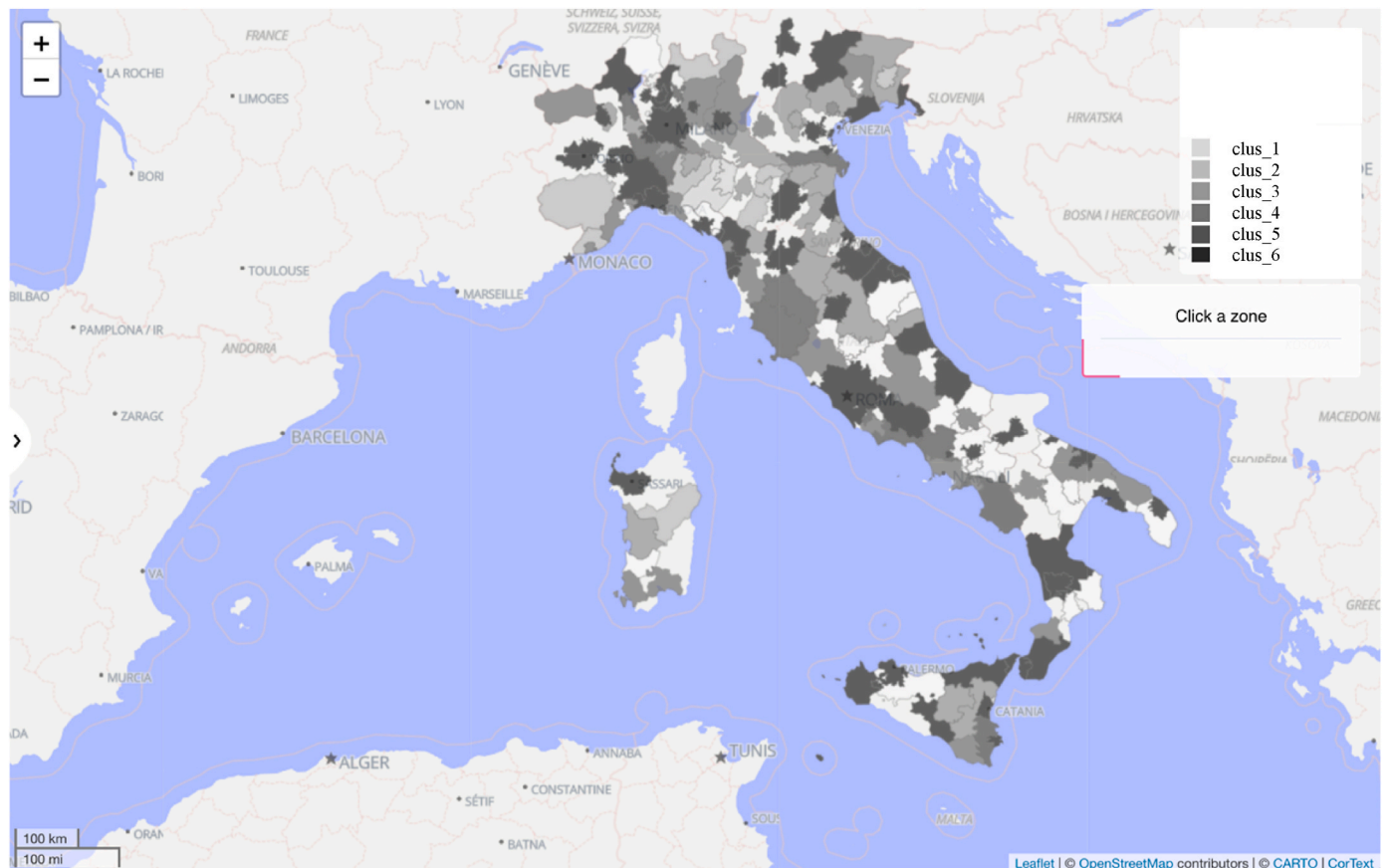
**Fig. 8.** – Clustering of the Italian URAs.

Table 4

– Mean economic variables of URAs in the clusters.

Cluster_id	clus_1	clus_2	clus_3	clus_4	clus_5	clus_6	Total
Inhabitants (mean)	192 325	228 338	259 634	353 495	239 258	415 358	345 498
Added value (mean)	2,34	0,70	0,50	0,15	0,22	0,18	0,30
Employees (mean)	24,07	8,80	7,77	2,85	4,27	3,17	4,65
Material asset (mean)	3,30	1,09	0,77	0,28	0,46	0,30	0,48
Sales (mean)	12,48	4,07	3,45	0,98	1,37	1,10	1,85
Consortium density (mean)	23,64	16,38	10,65	7,94	16,39	2,42	7,34
Number of consorted firms (mean)	224,04	69,15	19,66	11,43	41,33	2,07	17,49
Number of consorted firms per consortia (consortia size) (mean)	10,43	4,83	2,68	1,93	3,21	0,55	1,83
Patent agri-food density (mean)	32,50	14,89	7,41	4,60	2,15	8,19	7,53
Agri-food patent specialisation (mean)	1,71	2,11	1,09	0,66	0,94	1,42	1,21
Patent density (overall technological intensity) (mean)	48,52	34,57	31,69	35,69	31,94	30,05	32,15

Table 5

– Mean conditional efficiency and variance of URAs in the clusters.

Cluster_id	clus_1	clus_2	clus_3	clus_4	clus_5	clus_6	Total
Conditional efficiency (mean)	0,92	0,88	0,81	0,78	0,76	0,71	0,76
Conditional efficiency (variance)	0,01	0,04	0,03	0,03	0,02	0,05	0,04

The main limitations of our study, which could be addressed in future research, are related to the choice of variables. Variables reflecting the three forms of capital could be expanded to include research projects and relationships with universities, providing more comprehensive measures of intellectual capital. Additionally, the impact of public intervention in agriculture, which significantly influences rural development, could be further explored to enrich the analysis. Future research should explore how internal relational capital in patent creation can enhance patent production itself, and consequently, agricultural efficiency. This study contributes to a deeper understanding of the role of intellectual capital in rural development and provides valuable insights for policymakers and agricultural practitioners.

CRedit authorship contribution statement

Pierluigi Toma: Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Patricia Laurens:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Investigation, Conceptualization.

Data availability

Data will be made available on request.

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