



HAL
open science

Regional Heterogeneities and Intellectual Capital: unveiling the impact between innovation and tradition

Pierluigi Toma, Patricia Laurens

► **To cite this version:**

Pierluigi Toma, Patricia Laurens. Regional Heterogeneities and Intellectual Capital: unveiling the impact between innovation and tradition. *Socio-Economic Planning Sciences*, 2024, 96, pp.102087. 10.1016/j.seps.2024.102087. hal-04745720

HAL Id: hal-04745720

<https://hal.science/hal-04745720v1>

Submitted on 21 Oct 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0
International License

Regional Heterogeneities and Intellectual Capital: unveiling the impact between innovation and tradition

Pierluigi Toma, Department of Economics and Management, University of Salento, 73100, Lecce, Italy

Patricia Laurens, LISIS, Univ Gustave Eiffel, ESIEE Paris, CNRS, INRAE, 77447, Marne-la-Vallée, France

Abstract

The importance of regional development, especially in rural areas, has increased in the globalized world, with a focus on the relationship between economic development and the territory. Intellectual capital, consisting of human capital, relational capital, and structural capital, is crucial for rural development. 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 long tradition and 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. Too much concentration of different consortia in the same area does not favor efficiency but results in negative externalities. In contrast, innovation has a positive effect on efficiency at any level. A synergy effect was evidenced with the coexistence of both technological innovation and certification activities. We also study how the efficiency also varies according to regional characteristics such as the location of the region in Italy (north versus Center and south), the type of the regions (urban versus rural) or the size.

Introduction

Rural development is becoming increasingly important in the globalized scenario. The new urban flows and the growing demand for a new post-covid normality place at the center the relationship between economic development and the territory to which it belongs, in a context of strong international competitiveness. The sector that is mainly susceptible to a strong relationship with the territory is certainly the agri-food sector.

In this regard, intellectual capital represents the driving force for regional development in rural zones, through its three pillars: human capital, relational capital and structural capital. Intellectual capital, in relation to the concept of rural and urban areas, encompasses two fundamental aspects: innovation and tradition. In the agri-food sector, this is decisive in being able to fully outline the effect of intellectual capital. In fact, it is customary to believe (wrongly) that the agri-food sector is characterized by a low capacity for research, development and innovation. On the other hand, that it is unable to enhance the tradition of know-how that for decades (if not centuries) has been handed down as knowledge.

Well, in the scientific literature there are very few works that have measured, from a quantitative point of view, the impact of intellectual capital in rural development. The Italian context is particularly interesting from this point of view. In fact, 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 specificities. The concept of heterogeneity also concerns the profound divergences between urban and rural areas. The geographic area concept adopted in this paper captures these all-important policy and investment divergences. Furthermore, the Italian agro-food sector is also characterized by a great dynamism in terms of scientific-technological research, with the production of patents.

Therefore, the aim of this work is to measure the impact of intellectual capital and know-how on regional development in the agricultural sector, through the combination of an original and innovative approach.

In this paper we apply a nonparametric efficiency methodology, therefore without any a priori assumption, to a unique geographic area-based dataset. This makes the model extremely flexible and suitable for 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 sets the hypothesis of the work. Then it details the implemented methodology, a nonparametric efficiency methodology applied at a local regional level, and the data we have used. A final section describes and discusses the results. First it evidences how the patent density and consortium density contribute to improve the efficiency in the agri-food industry. At last, it tries to evaluate to which extent this improvement could be correlated to some intrinsic characteristics of the regional areas (geographical, economical or size parameters).

Literature Review

The vital role of agriculture is unquestionable, due to the human welfare reliance on agricultural production, in terms of its amount and stability (Angulo, 2019) and the tight boundary that links it to the environment. Being highly connected with the territory, agri-food firms are exploring a singular landscape, by experiencing a more integrated approach to regional and local realities, compared to the past. While the global trade liberalization of food is promptly incurring, humanity is simultaneously witnessing a reassertion of agricultural products with regional and local identities

- *The agri-food system*

The concept of agri-food system has been suggested, long ago by the rural economist Malassis and is mainly used at the global scale (Malassis, 1996; Rastoin and Ghersi, 2010) and/or to qualify different kinds of agri-food models (Fournier and Touzard, 2014). The territorial role has been explored mostly through a paradigm of relocalisation (of production/consumption links), utilising notions such as the foodshed (Kloppenburg et al., 1996) or regional food systems (Clancy and Ruhf, 2010), and/or through a focus on the production side, as in the case of territorialised food systems (Bowen and Mutersbaugh, 2014).

It is critical for each territory to generate, replicate, and share its own knowledge, whether traditional or scientific-technical information, or a combination of the two, in order to ensure cultural sustainability (Farré-Ribes et al., 2019). The authors suggest how quality can be used to offer socioeconomic options for regions. The local production structure is made up of networks of small and medium businesses and agricultural farms that specialize in a narrow agro-food niche and are 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 (Sanz Cañada & Macías Vázquez, 2005). Given the usefulness of preserving the equilibrium between firms and territorial capital, both from the economic and physical perspective, over the years concerns about the agri-food industry's efficiency have sprung up.

- *The intellectual capital in the agri-food system*

The agricultural sector is the primary sector for measuring an important aspect when it comes to intellectual capital: the clash between tradition and innovation. In fact, nothing embodies the coexistence of these two aspects of knowledge, without one prevailing over the other, more than agriculture. The studies in this field are extremely fascinating, and the research trend is substantial and enduring (Chambers (1992), Hobsbawm & Ranger (2012), Agrawal (2002), Agrawal (2014)), constantly bringing forth new insights and conceptualizations (Cannarella & Piccioni 2011).

In this regard, intellectual capital represents the concept that encompasses all the value of knowledge, both traditional and innovative, which can generate an impact in the development of a territory, even in the agri-food sector. According to the ecosystem approach to create new value represented by the sharing of knowledge inside and outside the organization (Dumay and Garanina, 2013), Intellectual capital is a decisive factor for the development of a territory. This perspective “combines human, relational and structural capital into a new vision that considers the social aspect of IC” (Secundo et al., 2017). The literature therefore defines in a very strict way what intellectual capital is, and in this paper, we want to identify the most appropriate definitions according to the different pillars: human, relational and structural capital.

- The 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 (Ruault and Lemery, 2009). Thus, the importance of professional dialogues among peers to understand the logics of action (Lazega, 2001) and to more precisely to understand the dynamics of technical changes in agricultural practice has been highlighted (Compagnone, 2004; Compagnone and Hellec, 2015; Darré, 1996). Also, the social network analysis approach appeared promising to show the role of dialogic professional ties between peers in mastering technical changes (Compagnone and Hellec, 2015; Conley and Christopher, 2001; Foster and Rosenzweig, 1995; Houdart et al., 2011).

- The structural capital

As far as structural capital is concerned, literature has always defined patents as the fundamental fulcrum of this type of knowledge. (Mouritsen, J., & Koleva, G. 2005).

Patents are part of the firm's intellectual capital in the form of organisational capital (Roos et al., 1997; Stewart, 1997, Molodchik et al., 2019) in addition to other sources of intellectual capital like human capital and relationship capital and indeed other kinds of organisational capital such as databases and organisational processes. This is also true for the agricultural sector, although research and development activity seem less developed. The agro-food industry is usually considered to be a low-tech sector {Delvaux et al, 2018). In agro-food industry, there is a high concentration of patented technology in a few firms, but most of these are multinational companies (Alfranca et al., 2002, 2004). Many innovations in the agri-food field are product or process improvements, which follow an incremental logic, without changes in technology (Galizzi and Venturini, 1996; Grunert et al., 1997). This determines the fact that the agricultural and food industry enjoys the benefits deriving from patents born in other areas (Garcia Martinez and Briz, 2000; Traill and Meulenber, 2002).

For these characteristics, 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.

Several studies have pointed out that enterprises in the agri-food sector are highly dependent on external sources of information for innovation and hence must open their innovation process to their network (Avermaete et al., 2004; Sarkar and Costa, 2008).

The sources of knowledge external to the company are more decisive for innovation in the Agri-food sector (Avermaete and Viaene, 2002; Bröring, 2008). This shows that the sector lends itself

well as a case study of territorial and widespread knowledge, the result of relationships and connections between businesses, the territory and institutions, within a rural and non-rural area. 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 (Galizzi and Venturini, 1996); the machine tools and the electrical product sectors (Johnson and Evenson, 1999); and nanotechnology (Sanguansri and Augustin, 2006; Kalpana Sastry et al., 2009) or biotechnology (Levidow, 2002; Carew, 2005). Despite the heavy reliance of agri-food firms on previous scientific and technological knowledge, papers that have empirically analysed the science–technology links are rare.

- The relational capital

In addition to structural capital, the last pillar that remains to be explored in terms of scientific literature is relational capital. An interesting experience of relational capital can be identified in PDO products, especially with a view to developing a complex of relationships and knowledge (Micha et al. 2022). 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. (Farré-Ribes et al., 2019). Indeed, it has fostered the development of a sense of belonging to the region (Axelsson et al., 2013; Soini and Birkeland, 2014), which really is a critical component in the development of long-term territorial continuity policies.

The growing attention towards such productions, which started in 1992 with the establishment of Council Regulation n. 2081 for PDO and PGI and then replaced by Council Regulation EC 510/2006, is due to the following factors (Rangnekar, 2004; Arfini et al., 2010; Chinnici et al., 2012):

- a) Fight against counterfeiting and protection of fair competition.
- b) Protect typical productions from market speculation.
- c) Rural development for the enhancement and protection of the treasure of relationships and knowledge of a rural and urban area.
- d) Preservation of property and resources of rural territories.

As declared by Todeva & Knoke (2005), the exclusive use of a geographical name necessitates the formation of a producer collective; to control the use of the appellation, they must create a

producer group. This allows for better supervision, coordination, and implementation of the label's collaborative management incentives. PDOs and PGIs offer consumers a unique warranty of transparency on production methods, authenticity and health (Nayga et al., 1999; Canavari et al., 2002). Local items are cheap goods in a "local manufacturing environment" that are eligible for a PDO (Protected Denomination of Origin). These reasons lead us to consider the number of quality labels, for each rural or urban areas, as a proxy of human and relational capital, as they contain the know-how of the territory.

There are very few empirical works that have measured the impact of human capital on territorial development in the agri-food sector, especially involving measures that are not typical of this sector, such as patents and knowledge relations. This paper intends to bridge this gap, in order 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) 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.

Research Design

Efficiency in agriculture is heavily discussed. It often refers to the management of natural resources (Keating et al., 2010). In recent years, there have been increasingly rich analyses that evaluate the impact of external effects on the production process, which can heavily influence it. Agricultural output–input interactions is driven by causes of variability: climate, biological system variety and management differences among farms over the years. Agri-food industry is unpredictable and non-standardized owing to different business models, environmental variations impacting products and/or processes (Corallo et al., 2018).

An important aspect is undoubtedly 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) by taking into account environmental or other external factors that may affect their performance. The conditional efficiency approach was developed by Daraio and Simar in 2005 as an extension of the classic DEA model.

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.

Overall, the methodology of conditional efficiency is a valuable tool for assessing the efficiency of DMUs in the presence of external factors and can provide important insights into the drivers of efficiency.

Starting with Cazals et al. (2002) and Daraio & Simar (2005), we consider a production technology where the activity of the production units is characterized by a set of inputs $X \in R_+^p$ used to produce a set of outputs $Y \in R_+^q$ and $Z \in R_+^d$, generic vector of environmental variables.

We can define the attainable set $\Psi^z \subset R_+^{p+q}$ 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 (Daraio & Simar, 2005) 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 (Daraio & Simar, 2007b):

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

The choice of appropriate bandwidth selection is the focus of Daraio & Simar (2005, 2007a) and Bădin et al. (2010) studies. They are determined following the procedure adopted in Hall et al. (2004) and in Li & Racine (2007).

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. (2012). 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 to measure the impact of conditioning variables on efficiency. In particular, by adopting our output-oriented approach in which firms that maximize outputs with fixed inputs are favored, an increasing trend of this ratio vs the patent variable means that patents have a positive impact on efficiency. A negative trend means that patents have a negative impact on efficiency. The same thing obviously also applies to the other conditioning variable, i.e. the consortia. This result is extremely important because we do not impose a priori positive or

negative impact of these variables, but we verify it ex ante by studying the trend of Ro on the conditioning variables.

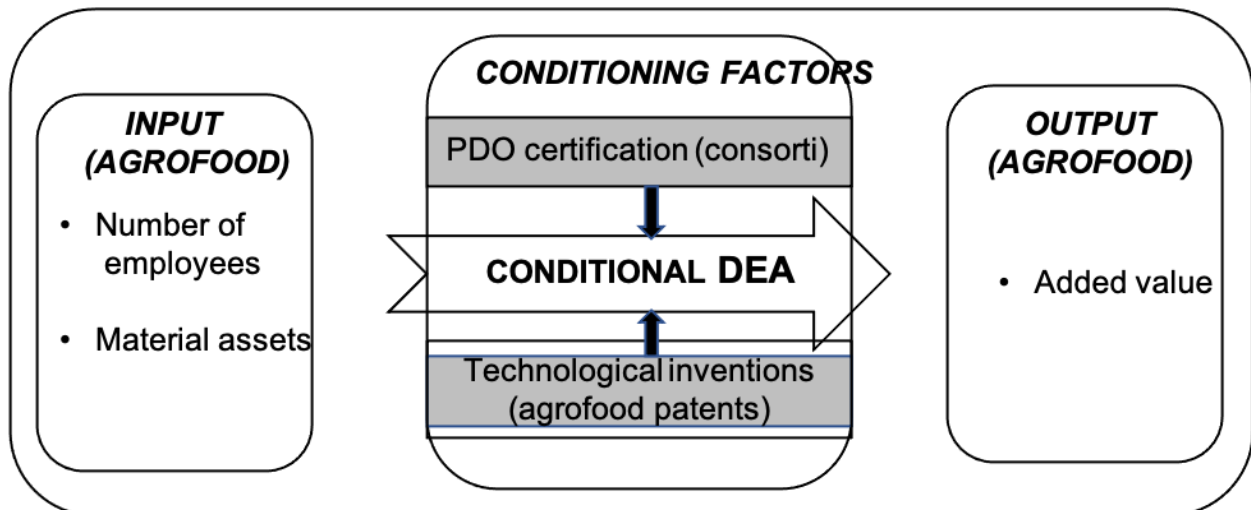
The nonparametric approach does not require the specification of the production functional form; however, we must make an assumption on the number of inputs and outputs. To limit the problem of the “curse of dimensionality”, our DEA conditional efficiency approach considers, besides the traditional input and output of the production function, as well as two environmental variables: the density of patents in agricultural field and density of PDO consorti. Table 1 explains the variables consider in our DEA conditional efficiency approach.

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

The input variable Labour is represented by the Number of employees, while material asset has been used as proxy for the capital variable. Added Value represents the output variable. Regarding external variables, as proxy of intellectual capital we adopt density of agri-food patents (structural capital) and density of PDO certification (human and relational capital). A schematic representation of the analysis is shown below.

Figure 1 – Schematic view of the efficiency analysis.



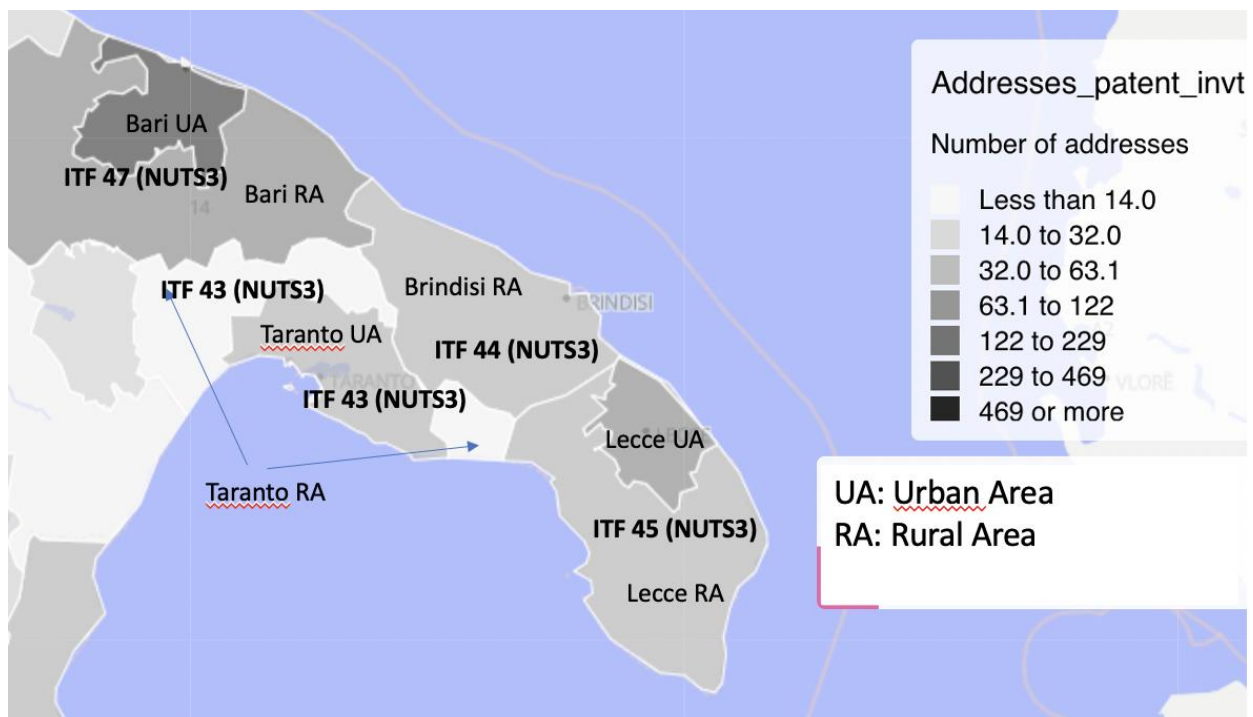
Materials

Data collection

The geographical units of our analysis are the Urban and Rural Areas (URA) boundaries (Villard and co.). For Urban Areas, we use the definition of the Functional Urban Areas (FUA)

built following a core analysis by population density with the addition with in addition areas that functionally depend on it (using commuting data) (ref.OECD , Lavalle, Kompil, & Aurambout, 2015, Outside these Urban Areas with the highest concentrations of inhabitants, new entities (Rural Areas) have been built to fill portions of geographical space which are outside urban areas. 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 (Patterson & Vaughn Kelso, 2014), i.e. NUTS3 regions in Europe (and Provinces in Italy). An example of Urban and Rural Areas in southern Italy is shown below where ITF45 NUTS3 region is split in two parts: Lecce Urban Area and Lecce Rural Area.

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



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

- Very small rural areas (rural areas below 50,000. All urban areas with a population below 50,000 have been withdrawn);
- Small (urban or rural) with population between 50,000 and 100,000;
- Medium-sized (urban or rural) areas: with population between 100,000 and 250,000;
- Metropolitan or rural areas: with population between 250,000 and 1.5 million;
- Large (rural or metropolitan) areas: with population above 1.5 million

Italy includes 153 URAs: 66 (43%) 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). 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.

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.

Patents

For the selection of agri-food patents, we follow the approach proposed by the Australian IP office to analyse 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 Australia Gouvernement 2014 and listed in Annexe 1). 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. 656 distinct priority patent applications were retrieved (which corresponds to 524 patents when summing the total fractional contribution of Italian inventors¹). 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.

Economic data

Finally, the agri-food economic strength of each URA was calculated by aggregating the agricultural sector companies with registered offices 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, total asset, has been extracted for each company belonging to each URA for the 2015-2020 time period.

In the following table we display the data accounting for the agri-food activity for each URA type. It is interesting to highlight that both Urban and Rural areas are committed in agri-food innovation. Almost all areas (178 among 184) report the presence of agri-food companies 4 out of 10 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.

¹ The difference relies to the presence of inventors located outside Italy among the patents with inventors based in Italy.

Table 2 – Agri-food activity in Italian URAs

URA type	Number of URA	Number of URA specialised in agri-food **	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*
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%

*: fractional counting of Italian inventors,

** : specialization in agri-food is measured based on patent data

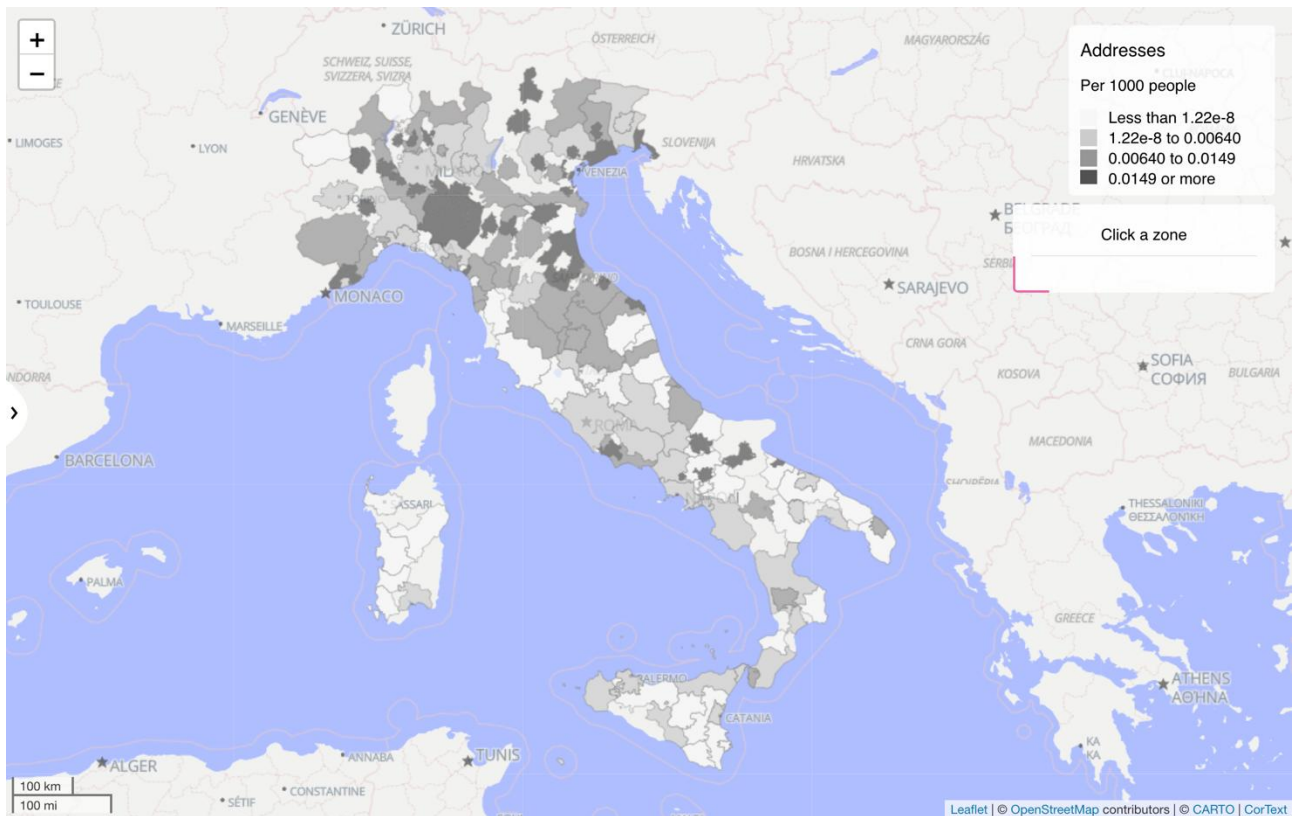
Results and Discussion

In this section, we present and discuss the empirical results of the efficiency analysis of rural and non-rural areas.

- **Summary statistics**

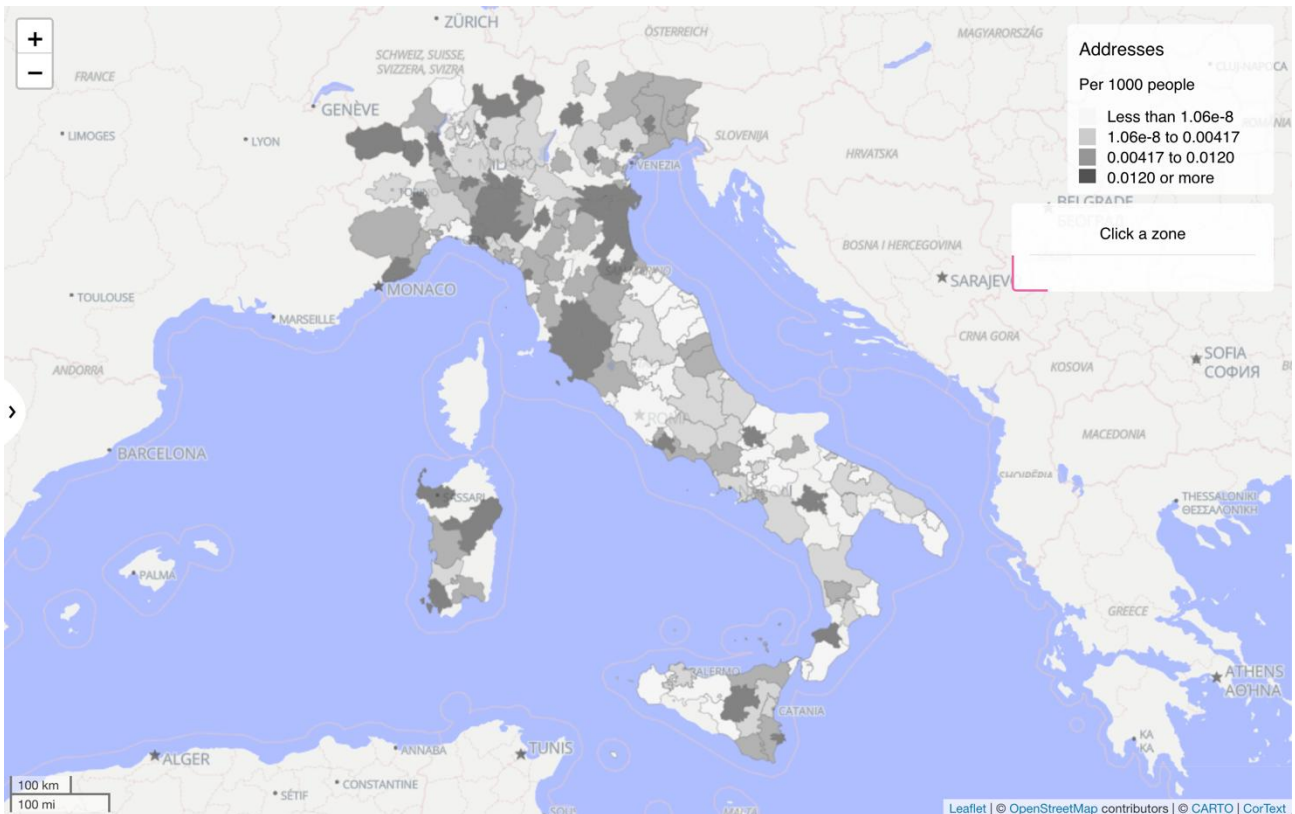
The geographical distribution of our environmental variables, patent density and consortia density among rural and non-rural areas in Italy are shown in Figures 3 and 4.

Figure 3 – Density of the patenting activity in Italian URAs



The agri-food patents follow the distribution of innovation in Italy: the higher densities are concentrated in the north, with few values in the center (Lazio) and a low level in the south. Is it interesting to relate this with the geographical diffusion of consortia, 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 is quite different.

Figure 4 – Density of the consortia in Italian URAs



Indeed, we can see that the peripheral areas (Sardinia, Campania, Sicily) have positive (green) values in a red “sea”. Areas with a large number 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 protected designation product recognized is easier in the north than in the south. This denounces a serious organizational and territorial development problem in the south.

The distributions of patents and consortia densities measured as the number of patents over the number of inhabitants (x 1M) across Italian URAs are very skew. The distribution of URAs with a patent density above the median value is unevenly distributed in Italy. 79% of URAs in northern Italy have a patent density above the median value. In central Italy and southern Italy respectively 44% and 20% of the URAs are above the median value of the patent activity.

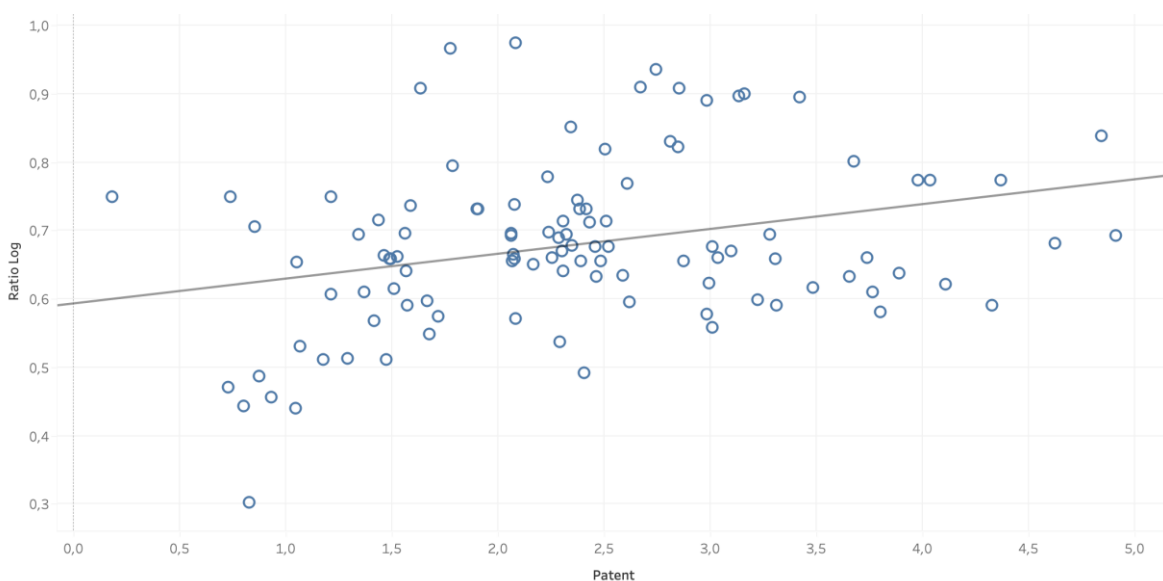
Quite similarly to patent density, northern Italy concentrates a high share of URAs (73%) with a consortia density above the median value. This share is equal to 41% in central Italy and to 30% in southern Italy.

At last, 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.

- *The conditional efficiency: effects of patent density and consortia density*

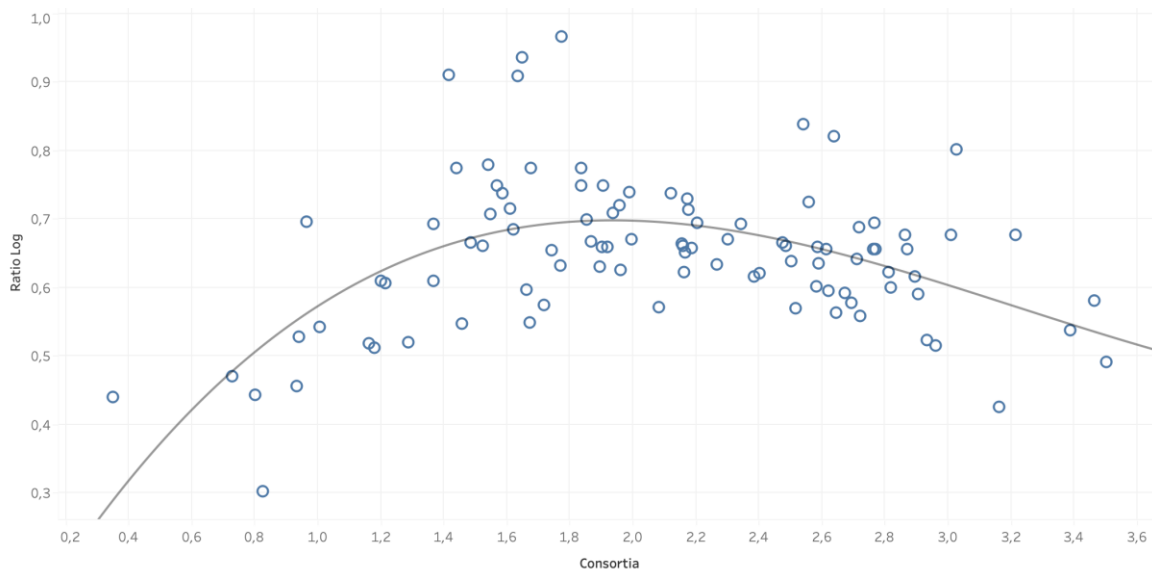
First, we investigated if there is any effect of consortia and patent densities on the level of efficiency. The full frontier ratio shown below, illustrated from a marginal point of view, shows a clear effect of patent density on the shape of the frontier, with a strong and clear a positive effect. This 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.

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



Concerning the effect of the consortia density, the result is a bit different with a nonlinear effect. For small to medium level of consortia intensity there is a positive effect on the efficiency, followed by a negative effect. This means that the consortia presence is very important with a strong effect for small number of consortia per inhabitants. Then, there is a “saturation effect” with a light negative effect on efficiency due to 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.

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



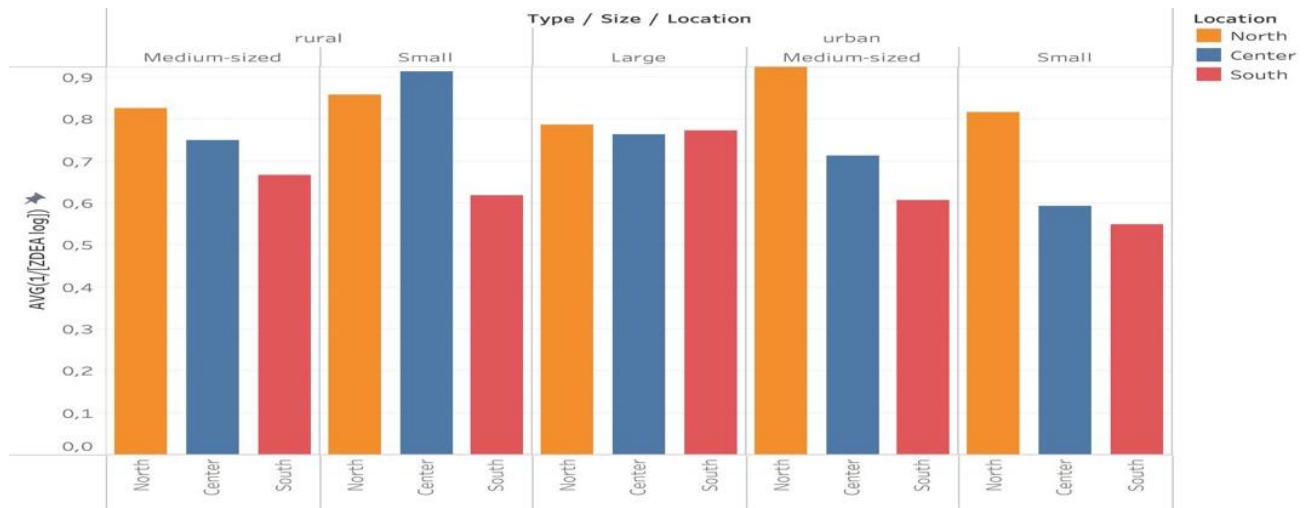
This section, evidencing that the local innovative capacities and product certification can positively affect the local agri-food economy, has answered our first research question. Considering that the agri-food system is dual with an agro-industrial model linked to the development of technologies and 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).

- *Modulating contribution of the URA heterogeneities on the conditional efficiency*

Furthermore, we continue the analysis by examining the relationship between conditional efficiency and the attributes that characterise the URAs. The attributes are related to the geography of the URA: the location of the URA (north/central/south), the type (rural or urban) and the size of the URA. These dimensions refer to the heterogeneity of the Italian context studied.

The overall results, which show the average conditional efficiency according to the geographical characteristics of the URAs, are presented below.

Figure 7 – Mean conditional efficiency in Italian URAs according to their location, size and type



Several interesting features can be observed:

- There is no clear difference between rural and urban areas: both types of areas can benefit equally from their intellectual capital to boost their agri-food economies.

- However, the size and location of the URAs seem to play a role:

- o The south of Italy benefits less than the north or the centre. This is true everywhere except for the southern metropolitan areas: southern metropolitan areas perform as well as central or northern metropolitan areas. This is an important finding in the Italian context.

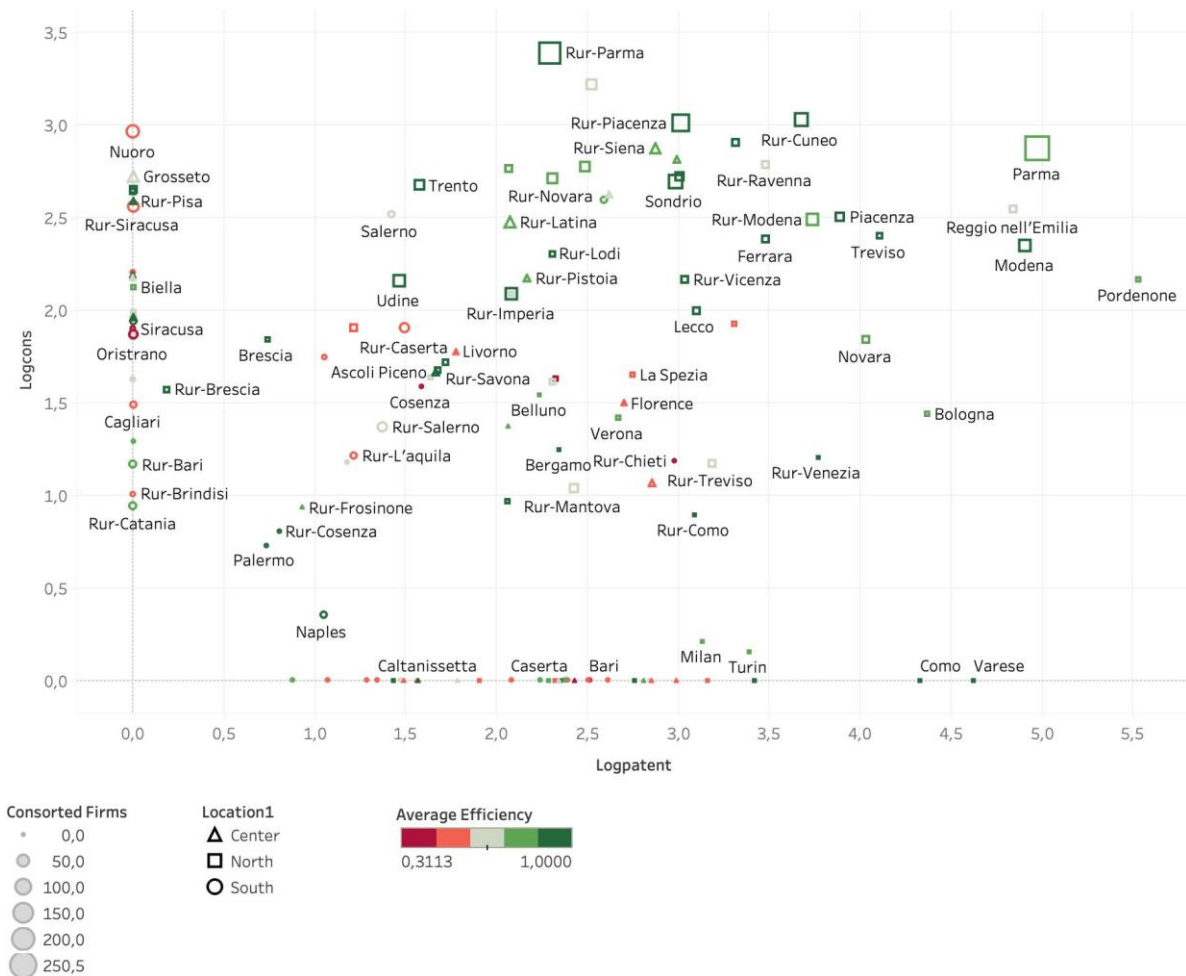
- o Size is not a relevant parameter. On average, small areas can perform as well as large areas. This is true for small northern areas (urban or rural), but also for small rural areas in central Italy. For small areas, rural areas tend to perform better than urban areas. However, this is not so obvious for medium-sized areas.

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). 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: increasing the patent density or the consortia density tends to increase the conditional efficiency, but 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). The two types of capital, structural capital and network capital, when both are available in the same area, 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.

Figure 8 – Consortium density (logcons), patent density (logpatent) and conditional efficiency in Italian URAs (rur-: Rural ; else Urban)



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 (taking into account their attributes: economic variables, geographical variables and agri-food intellectual capital) and then analysing whether we could find significant differences in the level of conditional efficiency between the clusters.

The results of the cluster analysis, taking into account all the variables available, make it possible to identify six clusters that capture well the heterogeneity between clusters and the homogeneity within clusters (Tables 3 to 5, Figure 9). They 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 and the mean values of the variables related to the local economy and the agri-food activity of the URAs are shown below.

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.

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%

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

Interestingly, we found similarities but also differences in the mean conditional efficiency between the different clusters:

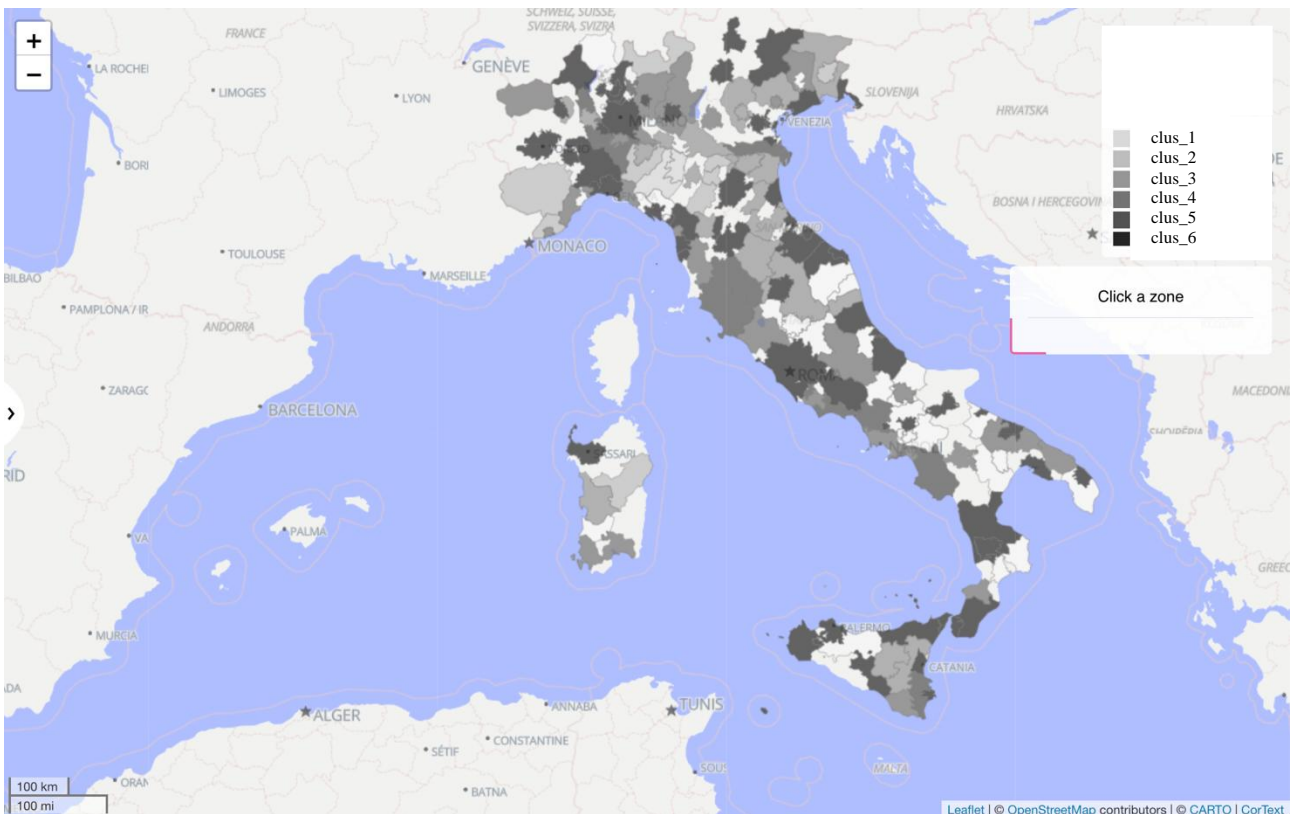
Cluster_1 and Cluster_2, which together represent 7% of the URAs, contain a limited number of URAs with a very high conditional efficiency (mean ≥ 0.88). These URAs are mostly located in rural areas of Northern Italy (in particular in the Parma region, the two top URAs, or in other regions of Emilia 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 agro-food sector is quite significant: the density of patents in the agro-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 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 agro-food economy. The URAs are mainly located in Emilia-Romagna (8 URAs), Venetia (5 URAs) and Lombardia and Toscana. The real difference between Cluster 2 and Cluster 3 is 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 agro-food economy, but also to their poor performance in agro-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), indicates the existence of a number of URAs with 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: it includes large areas, mainly in the centre, as well as small urban areas from the centre and south (Puglia, Calabria, Sicily, Toscana), but also 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.

Figure 9 – Clustering of the Italian URAs



These results firstly confirm our previous assumptions. The combination of both traditional and innovative activities in the agri-food sector allows 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, first of all 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 also often specialised in agri-food. 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. Consortia 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, in order to fully benefit from the presence of local PDO certification, it seems that both the density and the size of consortia need to be taken into account. The multiplication of the presence of small consortia in a given territory is detrimental to regional efficiency, while larger and fewer consortia are 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-food sector, northern (or central) Italy often performs better on average than southern Italy. The northern regions are the places where there are medium-sized rural or urban areas with a very dynamic agri-food sector, thanks to their capacity to maintain both traditional and innovative activities in an efficient way (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.

Conclusion

Intellectual capital is increasingly recognized as a critical element in the development of rural areas, especially in the current globalized scenario, where urban flows and demand for a new post-COVID normality have heightened the need for economic development that corresponds to the territory to which it belongs. The agri-food sector is the industry that is most closely tied to the territory in which it operates. Within this context, intellectual capital, which comprises human capital, relational capital, and structural capital, is the driving force for rural development (Nemes & Tomay 2022; Bowen & Miller 2022). 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. There is a misconception that the agri-food industry has a low capacity for research, development, and innovation, but this notion is unfounded, as it has a long tradition of know-how that has been passed down for centuries. Despite the significance of intellectual capital in rural development, there is a paucity of works that have quantitatively measured its impact. The Italian context is particularly interesting in this

regard, as its centuries-old tradition of agricultural methods and procedures is accompanied by a great territorial heterogeneity, which reflects the diverse regional specificities. 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. The Italian agro-food sector is also notable for its dynamism in scientific-technological research, which is evidenced by the production of patents. Therefore, the purpose 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 analysis findings emphasize the crucial role of intellectual capital in enhancing the efficiency of economic and agricultural activities within territories. Within the realm of intellectual capital, the innovative aspect represented by patents has a more pronounced influence on efficiency compared to the relational component. 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. On the other hand, 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.

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.

Acknowledgments

This work has been made possible thanks to the development of databases and analytic tools (Cortext platform) during the EU RISIS project funded under Horizon 2020 (Grant Agreement n°824091). The authors thanks Philippe Larédo for his careful reading of the manuscript and wise comments.

References List

Australian Government, Department of Industry, IP Australia (2014). The Australian food industry: a patent analytics reports (<https://nla.gov.au/nla.obj-411406582/view>)

Alfranca, O., Rama, R., & von Tunzelmann, N. (2002). A patent analysis of global food and beverage firms: the persistence of innovation. *Agribusiness: An International Journal*, 18(3), 349-368. doi: 10.1002/agr.10021

Alfranca, O., Rama, R., & von Tunzelmann, N. (2004). Innovation spells in the multinational agri-food sector. *Technovation*, 24(8), 599-614. doi: 10.1016/S0166-4972(02)00129-3

Agrawal, A. (2002). Indigenous knowledge and the politics of classification. *International social science journal*, 54(173), 287-297.

Agrawal, A. (2014). Indigenous and scientific knowledge: some critical comments. *Antropologi Indonesia*.

Angulo, A. M. (2019). Agriculture, human welfare and the environment: sustainability and rural viability revisited. *Sustainability*, 11(23), 6767.

Arfini, F., Belletti, G., & Marescotti, A. (2010). *Prodotti tipici e denominazioni geografiche: strumenti di tutela e valorizzazione*. Roma: Tellus.

Avermaete, T., & Viaene, J. (2002, June). On innovation and meeting regulation-the case of the Belgian food industry. In *DRUID Summer Conference on "Industrial Dynamics of the New and Old Economy-who is embracing whom* (pp. 6-8).

Avermaete, T., Viaene, J., Morgan, E. J., Pitts, E., Crawford, N., & Mahon, D. (2004). Determinants of product and process innovation in small food manufacturing firms. *Trends in food science & technology*, 15(10), 474-483. doi: 10.1016/j.tifs.2004.04.005

Axelsson, R., & Soini, K. (2013). Local food as a territorial development tool: analysis of local food strategies in Finland and Sweden. *European planning studies*, 21(11), 1763-1781.

Bădin, L., Daraio, C., & Simar, L. (2010). Optimal bandwidth selection for conditional efficiency measures: A data-driven approach. *European journal of operational research*, 201(2), 633-640. doi: 10.1016/j.ejor.2009.03.038

Bădin, L., Daraio, C., & Simar, L. (2012). How to measure the impact of environmental factors in a nonparametric production model. *European Journal of Operational Research*, 223(3), 818-833. doi: 10.1016/j.ejor.2012.06.028

Bowen, K. J., & Mutersbaugh, T. K. (2014). Localizing farm animal production: A global review. *Agriculture and human values*, 31(1), 101-113.

Bowen, R., & Miller, M. (2022). Provenance representations in craft beer. *Regional Studies*, 1-11.

Bröring, S. (2008). How systemic innovations require alterations along the entire supply chain: The case of animal-derived functional foods. *Journal on Chain and Network Science*, 8(2), 107-119. doi: 10.3920/JCNS2008.x093

Canavari, M., Bazzani, G. M., Spadoni, R., & Regazzi, D. (2002). Food safety and organic fruit demand in Italy: a survey. *British Food Journal*. doi: 10.1108/00070700210425688

Cannarella, C., & Piccioni, V. (2011). Traditionations: Creating innovation from the past and antique techniques for rural areas. *Technovation*, 31(12), 689-699.

Carew, R. (2005). Science policy and agricultural biotechnology in Canada. *Applied Economic Perspectives and Policy*, 27(3), 300-316. doi: 10.1111/j.1467-9353.2005.00251.x

Carlucci, F., Cirà, A., Immordino, G., Ioppolo, G., & Yigitcanlar, T. (2017). Regional heterogeneity in Italy: Transport, devolution and corruption. *Land use policy*, 66, 28-33.

Cazals, C., Florens, J. P., & Simar, L. (2002). Nonparametric frontier estimation: a robust approach. *Journal of econometrics*, 106(1), 1-25. doi: 10.1016/S0304-4076(01)00080-X

Chambers, R. (1992). Rapid but relaxed and participatory rural appraisal: Towards applications in health and nutrition. International Nutrition Foundation for Developing Countries.

Chinnici, G., Scuderi, A., & Pecorino, B. (2012). La percezione della qualità dei prodotti tipici da parte del consumatore in Sicilia. *La percezione della qualità dei prodotti tipici da parte del consumatore in Sicilia*, 143-172.

Clancy, K., & Ruhf, K. (2010). Regional food systems: An exploration of terms. *Journal of Hunger & Environmental Nutrition*, 5(4), 409-421.

Compagnone, C. (2004). La mise en oeuvre des innovations par les agriculteurs: quels enseignements tirer des modèles d'apprentissage?. *Cahiers Agricultures*, 13(5), 399-404.

Conley, T. G., & Christopher, E. (2001). Social networks and the implementation of innovations. *Journal of Evolutionary Economics*, 11(3), 271-296. doi: 10.1007/s001910000050

Corallo, A., Latino, M. E., & Menegoli, M. (2018). From industry 4.0 to agriculture 4.0: a framework to manage product data in agri-food supply chain for voluntary traceability. *International Journal of Nutrition and Food Engineering*, 12(5), 146-150. doi: 10.5281/zenodo.1316618

Daraio, C., & Simar, L. (2005). Introducing environmental variables in nonparametric frontier models: a probabilistic approach. *Journal of productivity analysis*, 24, 93-121. doi: 10.1007/s11123-005-3042-8

Daraio, C., & Simar, L. (2007a). Conditional nonparametric frontier models for convex and nonconvex technologies: a unifying approach. *Journal of productivity analysis*, 28, 13-32. doi: 10.1007/s11123-007-0049-3

Daraio, C., & Simar, L. (2007b). *Advanced robust and nonparametric methods in efficiency analysis: Methodology and applications*. Springer Science & Business Media.

Delvaux, B., Oheix, A., & Vivien, F. D. (2018). Agro-food industry and low-tech sectors: Specificities and complementarities. *Procedia Manufacturing*, 22, 613-619. doi: 10.1016/j.promfg.2018.03.170

Dumay, J., & Garanina, T. (2013). Intellectual capital research: A critical examination of the third stage. *Journal of Intellectual Capital*, 14(1), 10-25.

Farré-Ribes, M., Gracia-Roman, J., & Ortigosa-Blanch, A. (2019). Quality and rural sustainability: a multidimensional analysis of the culture of quality in the wine sector in Spain. *Sustainability*, 11(19), 5282.

Foster, A. D., & Rosenzweig, M. R. (1995). Learning by doing and learning from others: Human capital and technical change in agriculture. *Journal of Political Economy*, 103(6), 1176-1209. doi: 10.1086/601447

Fournier, S., & Touzard, J. M. (2014). The diversity of territorial agri-food systems: A review. In *A territorial approach to food security under climate change* (pp. 11-34). Springer, Cham.

Galizzi, G., & Venturini, L. (1996). Product innovation in the food industry: nature, characteristics and determinants. In *Economics of innovation: The case of food industry* (pp. 133-153). Physica-Verlag HD. doi: 10.1007/978-3-642-50001-5_8

Grunert, K. G., Harmsen, H., Meulenber, M., Kuiper, E., Ottowitz, T., Declerck, F., ... & Göransson, G. (1997). A framework for analysing innovation in the food sector. *Products and process innovation in the food industry*, 1-37. doi: 10.1007/978-1-4613-1133-1_1

Hall, P., Racine, J., & Li, Q. (2004). Cross-validation and the estimation of conditional probability densities. *Journal of the American Statistical Association*, 99(468), 1015-1026. doi: 10.1198/016214504000000548

Hobsbawm, E., & Ranger, T. (Eds.). (2012). *The invention of tradition*. Cambridge University Press.

Houdart, M., Mathevet, R., & Lemery, B. (2011). Agronomists' professional mobility and the circulation of plant genetic resources: A case study in Southern France. *Sociologia Ruralis*, 51(4), 412-429. doi: 10.1111/j.1467-9523.2011.00529.x

Johnson, D. K., & Evenson, R. E. (1999). R&D spillovers to agriculture: Measurement and application. *Contemporary Economic Policy*, 17(4), 432-456. doi: 10.1111/j.1465-7287.1999.tb00695.x

Kalpana-Sastry, R., Rashmi, H. B., Rao, N. H., & Ilyas, S. M. (2009, July). Nanotechnology and agriculture in India: the second green revolution. In OECD conference on "Potential environmental benefits of nanotechnology: fostering safe innovation-led growth" Session (Vol. 7, pp. 15-17).

Keating, B. A., Carberry, P. S., Bindraban, P. S., Asseng, S., Meinke, H., & Dixon, J. (2010). Eco-efficient agriculture: Concepts, challenges, and opportunities. *Crop science*, 50, S-109. doi: 10.2135/cropsci2009.10.0594

Kloppenburg, J., Jr, Hendrickson, J., & Stevenson, G. W. (1996). Coming in to the foodshed. *Agriculture and Human Values*, 13(3), 33-42.

Lazega, E. (2001). *The collegial phenomenon: The social mechanisms of cooperation among peers in a corporate law partnership*. Oxford University Press.

- Levidow, L. (2002). Ignorance-based risk assessment? Scientific controversy over GM food safety. *Science as Culture*, 11(1), 61-67. doi: 10.1080/09505430120115725
- Li, Q., & Racine, J. S. (2007). Nonparametric econometrics: theory and practice. Princeton University Press.
- Malassis, L. (1996). Globalization and Agri-Food Systems: A Challenge for the 21st Century. FAO, Rome.
- Martinez, M. G., & Briz, J. (2000). Innovation in the Spanish food & drink industry. *The International Food and Agribusiness Management Review*, 3(2), 155-176. doi: 10.1016/S1096-7508(00)00033-1
- Micha, E., Vigani, M., Vlahos, G., Tsakalou, E., & Maye, D. (2022). Protected Designation of Origin food chain arrangements: leveraging market power for small-scale producers in marginal regions. *Regional Studies*, 1-13.
- Molodchik, M., Zelenkov, Y., & Lomonosova, M. (2019). Corporate intellectual capital management: State of the art and a future research agenda. *Journal of Intellectual Capital*, 20(5), 1065-1089. doi: 10.1108/JIC-04-2019-0061
- Mouritsen, J., & Koleva, G. (2005). Intellectual capital management: Patents and innovation. *Journal of Intellectual Capital*, 6(4), 536-552. doi: 10.1108/14691930510634690
- Nayga, R. M. (1999). Retail health marketing: evaluating consumers' choice for healthier foods. *Health marketing quarterly*, 16(4), 53-65. doi: 10.1300/J026v16n04_05
- Nemes, G., & Tomay, K. (2022). Split realities—dilemmas for rural/gastro tourism in territorial development. *Regional Studies*, 1-10.
- Rangnekar, D. (2004). The socio-economics of geographical indications. UNCTAD-ICTSD Project on IPRs and Sustainable Development, Issue Paper, 8, 13-15.

Rastoin, J. L., & Gherzi, G. (2010). *Agri-food economics and sustainable development policy*. Springer Science & Business Media.

Roos, G., Pike, S., & Fernstrom, L. (1997). Intangible assets: The foundations of corporate profitability. *Long Range Planning*, 30(3), 425-438. doi: 10.1016/S0024-6301(97)90228-3

Ruault, C., & Lemery, B. (2009). Professional dialogues among farmers: a powerful approach to foster agroecological innovations in France. In *Proceedings of the 2nd ISO FAR Conference* (pp. 407-410).

Sanguansri, P., & Augustin, M. A. (2006). Nanoscale materials development—a food industry perspective. *Trends in Food Science & Technology*, 17(10), 547-556. doi: 10.1016/j.tifs.2006.04.010

Sanz Cañada, J., & Macías Vázquez, A. (2005). The geography of traditional foods: The case of a Spanish artisan cheese. *The Geographical Journal*, 171(1), 70-81.

Sarkar, S., & Costa, A. I. (2008). Dynamics of open innovation in the food industry. *Trends in Food Science & Technology*, 19(11), 574-580. doi: 10.1016/j.tifs.2008.09.006

Secundo, G., Del Vecchio, P., & Passiante, G. (2017). Human, relational and structural capitals in supporting the growth of intellectual capital. *Journal of Intellectual Capital*, 18(1), 141-158.

Soini, K., & Birkeland, I. (2014). Promoting regional food production and consumption in Norway: policy lessons from two counties. *Journal of Rural Studies*, 36, 386-397.

Todeva, E., & Knoke, D. (2005). Strategic alliances and models of collaboration. *Management decision*, 43(1), 123-148. doi: 10.1108/00251740510572533

Traill, W. B., & Meulenbergh, M. (2002). Innovation in the food industry. *Agribusiness: an International Journal*, 18(1), 1-21. doi: doi.org/10.1002/agr.10002

Villard, L., Ospina, J. P. & Medina, L. D. (2019). CorText Geospatial Exploration Tool. ESIEE Paris, Paris Est University. <https://docs.cortext.net/cortext-geospatial-exploration-tool/>

Annexe 1: Selection of agri-food patents

We follow the methodology proposed by the Australian Intellectual Property Office (Australian Government, 2014) to identify the food related patents. In that study, food patents were identified by International Patent Classification (IPC) searches and keyword searches. A list of descriptors for the IPC classes and the keywords used to search titles and abstracts of patent documents are given below.

The range of food technologies identified in the search includes ingredients, quality control, processing machinery and tools, and packaging, among others.

a) IPC selection

IPC = A01J* OR A21* OR A22* OR A23B* OR A23C* OR A23D* OR A23F* OR A23G* OR A23J* OR A23L* OR A23N* OR B02B* OR C12C* OR C12F* OR C12G* OR C12H* OR C12J* OR C12L* OR C13*

Description of searched marks: IPC	Description of IPC
A01J	Manufacture of dairy products.
A21B	Bakers' ovens; machines or equipment for baking.
A21C	Machines or equipment for making or processing doughs; handling baked articles made from dough.
A21D	Treatment, e.g. preservation, of flour or dough for baking, e.g. by addition of materials; baking; bakery products; preservation thereof.
A22#	Butchering; meat treatment; processing poultry or fish.
A23B	Preserving, e.g. by canning, meat, fish, eggs, fruit, vegetables, edible seeds; chemical ripening of fruit or vegetables; the preserved, ripened, or canned products.
A23C	Dairy products, e.g. milk, butter, cheese; milk or cheese substitutes; making thereof.
A23D	Edible oils or fats, e.g. margarines, shortenings, cooking oils.
A23F	Coffee; tea; substitutes; manufacture, preparation, or infusion thereof.

A23G	Cocoa; cocoa products, e.g. chocolate; substitutes for cocoa or cocoa products; confectionery; chewing gum; ice-cream.
A23J	Protein compositions for foodstuffs; working-up proteins for foodstuffs; phosphatide compositions for foodstuffs.
A23L	Foods, foodstuffs, or non-alcoholic beverages; their preparation or treatment, e.g. cooking, modification of nutritive qualities, physical treatment; preservation of foods or foodstuffs, in general.
A23N	Machines or apparatus for treating harvested fruit, vegetables, or flower bulbs in bulk, not otherwise provided for; peeling vegetables or fruit in bulk; apparatus for preparing animal feeding-stuffs.
A23P	Shaping or working of foodstuffs, not fully covered by a single other subclass.
B02B	Preparing grain for milling; refining granular fruit to commercial products by working the surface.
C12C	Brewing of beer.
C12F	Recovery of by-products of fermented solutions; denaturing of, or denatured, alcohol.
C12G	Wine; other alcoholic beverages; preparation thereof.
C12H	Pasteurisation, sterilisation, preservation, purification, clarification, ageing of alcoholic beverages or removal of alcohol therefrom.
C12J	Vinegar; its preparation.
C12L	Pitching or depitching machines; cellar tools.
C13#	Sugar industry

b) Lexical query in patent title or patent abstract

Lexical query = (food* OR edib?? OR eatab?? OR comestib?? OR eating OR snack? OR confection* OR beverage? OR soft_drink? OR condiment? OR fruit? OR vegetable?)
AND (fridge? OR refrigerat* OR (cold_room?) OR processing OR cook* OR evapo?rat* OR dissolv* OR filter* OR blend* OR cut? OR cutting OR chop? OR chopping OR corer? OR coring OR boil* OR steam* OR (deep_fry*) OR nozzle? OR spray* OR valve? OR conveyer? OR extrusion? OR extrud* OR form OR forming OR dehydrat* OR electrolyte? OR membrane? OR packag* OR container? OR

jar OR bottle? OR bottling OR canning OR storing OR storage OR wrap* OR measur* OR weigh* OR analy* OR temperature? OR thermometer? OR instrument? OR device?)

Note: * denotes unlimited truncation

? denotes one or zero character

_ denotes white space or a hyphen

c) Distribution of technological fields in the agri-food patent corpus

We characterize the distribution of technologies in our set of agri-food patents using the 35 technological field classification defined by WIPO (https://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf). Not surprisingly, one third of them deal with food chemistry, almost 20% to handling technologies (packaging, storage, transportation of products) and 9% to equipment for planting, harvesting or transforming agri-food products (Other special machines).

