Sustainable Local Development and Smart Specialisation Strategies: Recent Developments in Agri-food Research and Innovation Partnerships in Puglia, Italy

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Abstract. This paper investigates how agri-food research and innovation (R&I) activity may interact with sustainable local development processes. The focus is on smart specialisation strategies and partnerships between agri-food business and research organisations, established under the open innovation paradigm. An exploratory study is carried out on recent (2010–19) agri-food R&I activity in Puglia (Italy), covering both projects and patents carried out by 47 research centres (affiliated to any of 11 research institutions) and 40 agri-food enterprises. Beside project data analysis based on categorisation, the methodology applied social network analysis to partnerships. Findings point to Sustainable Manufacturing and Human and Environmental Health being the prevalent target areas of innovation activity, thus resulting in some form of sustainable agricultural intensification, with a bias towards Industrial Biotechnology, Advanced Materials and Nanotechnology. Open innovation approaches seem to be still phasing in, and the innovation potential of agri-food enterprises appears to be largely untapped. Future research may address the friction between industry-driven smart specialisation strategies and place-based innovation patterns that harness the intangible potential of social and relational capital.

Keywords: Agri-food sector · Open innovation · Smart specialisation · Food Systems · European innovation partnerships

1 Introduction

Researchers and innovators have been confronted with many challenges and wicked problems while aiming to support food and nutrition security for all [25, 30].

Sustainable development-oriented policy making has increasingly payed attention to food security and nutrition – as framed by Agenda 2030's Goal 2 "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" and other mutually reinforcing goals [19, 28].

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Against the background of these ambitious goals set by the global community, major challenges still need to be tackled, which include [11, 24]:

- pressure of a growing world population (expected to be about 9 billion by 2050 with 70% of the population in urban areas);
- climate change and other global environmental changes;
- economic inequalities and political instability;
- food safety issues and adverse nutrition behaviours and lifestyles, resulting in an increase in the rate of non-communicable, diet-related diseases (including coronary heart disease, stroke, and diabetes).

On top of delivering on unprecedented output targets, food systems are therefore expected to become fully nutrition-sensitive and planetary-boundaries compatible.

To that end, the "knowledge transfer" paradigm has inexorably shown its limitations, giving way to alternative approaches to knowledge exchange, learning and innovation.

Under the European Innovation Partnership "Agricultural Productivity and Sustainability" (EIP-AGRI), funded by the European Commission (EC)[1], an "interactive innovation model" became popularised: in its most advanced terms, knowledge is co-created by farmers, scientists, advisers, enterprises, NGOs and other stakeholders.

On the operational level, Agricultural Knowledge and Innovation Systems (AKIS) are understood as means to analyse and manage how farming practices, business models, regulations and funding programmes, expertise and research outputs interact within a country or a region [20]. It is apparent from the outcomes of an EU-funded research project [21] that the overall strength and the degree of integration of AKIS vary significantly across Europe (Fig. 1).

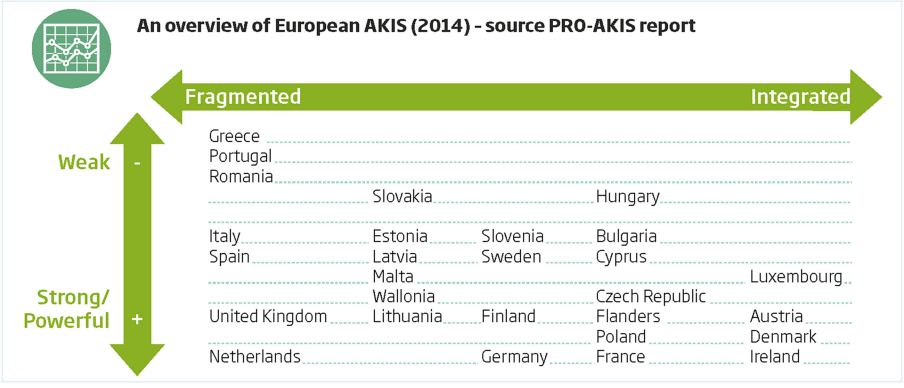

Fig. 1. An overview of the state of Agricultural Knowledge and Innovation Systems (as of 2014) in Europe. Source: EIP-AGRI [16], adapted after Knierim and Prager [21].

Within the rapidly evolving field of research and innovation studies, the Open Innovation (OI) concept has been recently gaining momentum, and it may be defined as "*a*

[1] https://ec.europa.eu/eip/agriculture/en.

distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and nonpecuniary mechanisms in line with the organization's business model" [6]. OI also considers the central role that users play in both value creation and as the beneficiaries of innovative products and services, thus including a well-functioning ecosystem that allows co-creation, whose members interact "*along and across industry and sector-specific value chains to co-create solutions to socio-economic and business challenges*" [12, 13: 13].

The links between the OI approach and the agri-food sector have been broadly explored in recent years. Under the auspices of a recent call for solutions promoted by a non-profit organisation[2], these links have been conceptualised as to include:

- shared value across food networks
- Internet of Things as a solution for precision agriculture
- tracing and tracking using blockchain
- climate change and variability adaptation strategies
- circular economy applied to agriculture.

On the whole, OI in the agri-food sector entails concerted efforts to: a) shift attention from the conceptual and operational framing of "knowledge transfer" to triggering "open innovation processes"; b) highlight any specificity of the agri-food sector with respect to OI approaches and; c) investigate synergies and frictions between agriculture/ rural development policy and regional innovation strategies.

As for the second and third issues, the lines of research carried out at the European Commission-Joint Research Centre's Institute for Prospective Technological Studies may help develop a comprehensive framework focusing on knowledge sharing: by 2016, a total of 85 EU regions had selected over 270 agri-food-related smart specialisation priorities – the most frequently identified being novel agri-food technologies, agri-food and tourism, and food with higher added value [5, 7].

Both European Innovation Partnerships and Smart Specialisation Strategies were launched by the EU in an attempt to place following research questions innovation at the heart of its integrated strategy for smart, sustainable and inclusive growth [14] – and framed in the Europe 2020 Flagship Initiative "Innovation Union" [15].

Hence, by prioritising agri-food innovations for strategic investments, some regions signalled the importance of the agri-food sector for their sustainable local development trajectories, within a broader trend towards harnessing the European Regional Development Fund to develop research and innovation capacity across Europe.

Based on activities carried out in the framework of the Interreg V-A Greece-Italy "Innovative Networks for the Agrifood Sector" project (Innonets), this paper aims at presenting some preliminary analyses concerning recent (2010–2019) research&innovation (R&I) activities (covering both projects and patents) in the agri-food sector in the Puglia region (Italy). Moving from a survey of research organisations and programmes, the work addresses the following research questions:

[2] Fondazione Giacomo Brodolini, Social Roots programme: www.socialroots.eu.

1. what is the focus of R&I activity in the agri-food sector in the target area?
2. is R&I activity evolving towards open innovation approaches?
3. is the regional smart specialisation strategy playing a role in linking R&I activity to sustainable local development?

To that purpose, the following Section introduces the context for R&I activity in the study area, while Sect. 3 illustrates the methodology adopted by the research team. After reporting on the preliminary results in Sect. 4, the paper closes with a brief discussion and some concluding remarks.

2 The Context of Research and Innovation Activity in Puglia, Italy

Puglia lies in South-eastern Italy; it stretches over almost 20.000 km^2 and hosts around 4 million inhabitants. It is mostly flat, except for the Monti Dauni range and the Gargano headland, which face each other across the main plain in the North (Tavoliere). Once dominated by extensive agriculture and few prominent trading centres, Puglia evolved into a mixed economy with a growing service sector and few industrial poles. There are 257 municipalities, mainly medium to small towns, grouped into a Metropolitan city (Bari) and five provinces.

According to the regional Smart Specialisation Strategy[3], the most promising agri-food research areas in Puglia concern traceability, quality and safety, biotechnologies, advanced sensor and microsystem technologies for precision farming, as well as a diversified array of technologies and methods for food preservation and processing. Among the many research initiatives that have been surveyed, production-driven R&I activities seem to prevail over processing- and marketing-oriented ones.

A preliminary investigation of innovation clusters in the agri-food sector identified 4 policy-driven clusters – one with a regional remit (the Agri-food Regional Cluster-D.A.RE.) and three local clusters, each covering the territory of 1 to 3 provinces and reflecting the local specialisation patterns:

- Jonico Salentino Agri-food cluster;
- Terre Federiciane Agri-food cluster;
- Plant nursery and Flower growing Cluster.

Moreover, the links between R&I supply and demand may be described following the outcomes of a recent study on innovation needs in the agri-food sector in Puglia[4] [26], and therefore investigated along 7 focus areas covering, among others, both traditional supply chains (such as the wine and oil's) and more innovative topics – having a bearing on food safety and sustainable agriculture.

[3] Adopted on 1 August 2014 by means of Resolution n. 1732 of the Regional Council of Puglia, concerning "*Strategia regionale per la Specializzazione intelligente - approvazione dei documenti strategici 'SmartPuglia 2020' e 'Agenda Digitale Puglia2020.'*"

[4] Commissioned by the regional government and carried out by the then National Institute for Agricultural Economics (INEA), now merged into the CREA-Council for research in agriculture and the analysis of agrarian economics.

The three main categories that may help trace either thematic or territorial links that hinge on R&I activities in Puglia are shown in Fig. 2, along with a few examples drawn from the abovementioned sources.

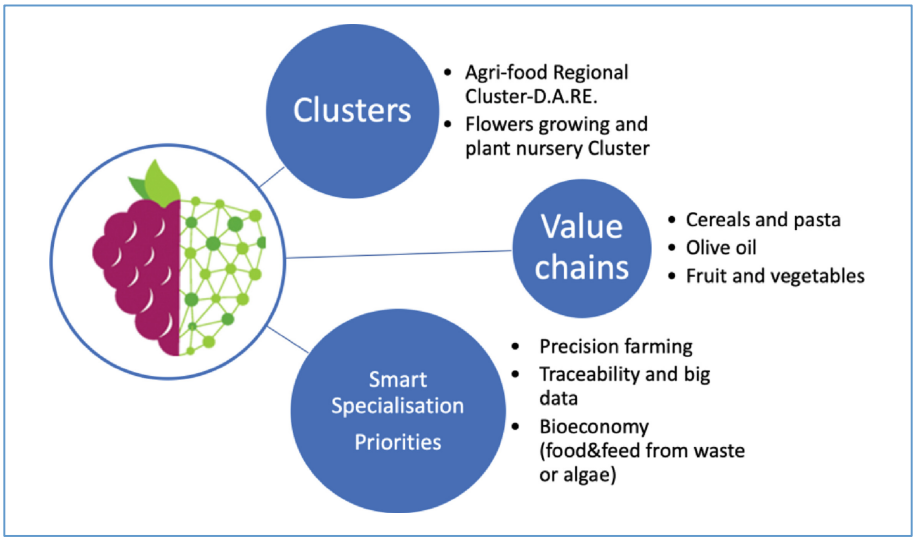

Fig. 2. A schematic conceptualisation of the main thematic or territorial links emerging from the R&I activity in the agri-food sector.

With a view to investigating the links between R&I activity in the agri-food sector and sustainable local development, it might be useful to sketch the spatial distribution of cultivated areas, by identifying the main crops and some specialisations that appear to be remarkable in terms of either local prevalence or market concentration at national level. By way of an example, within the framework of a prominent prevalence of a few cultivations at the regional level (with arable land accounting for almost 50% of the total utilised agricultural land, olive groves for about 33%, and vineyards for somewhat less than 10%), these are unevenly distributed across the provincial territories. Moreover, some specialisations on individual agri-food products – which would not stand out in regional statistical accounts of crop categories – are worth an in-depth analysis to screen for innovation potentials, given their remarkable share even at national level (it is the case of, among others, cherries, tomatoes and artichokes, which accounted, respectively, for 35%, 35% and 31% of the overall national production in 2012).

3 Methodology

The research design moved from a mapping exercise of all R&I centres and institutions with an active interest in the agri-food sector, located in the Puglia region. These were investigated and illustrated by focusing on both their organisation and outputs, according to a simplified framework, covering:

- a list of recently funded projects;
- awarded patents;
- active laboratory and spin-offs.

Work developed along a further screening of agri-food related research activities, based on an investigation of innovation clusters and of the links between R&I supply and demand links – as reflected in R&I policies and funding programmes. Both steps fed back into the mapping exercise new research organisations, which were then investigated according to the same criteria as in the previous step.

The complete dataset was further analysed and categorised according to the main concepts adopted under the regional Smart Specialisation Strategy: value chains, clusters, smart specialisation priorities and key enabling technologies.

Social network analysis (SNA) was then adopted for a quantitative evaluation of the structure of, and dynamics within, networks of R&I organisations, as identified based on collaborative activities. SNA is rooted in the studies of social relations and the characteristics of connections between individuals within groups or communities [23, 27]. While sharing the same theoretical bases, new fields of application have subsequently developed, such as organisational learning, management studies, and knowledge exchanges within research and development processes [29] or even, as close as possible to the approach chosen for this study, in investigating collaboration occurring in R&I projects [10].

SNA supported the ex-post analysis of the network of relationships between R&I partners, aiming to identify collaborative social phenomena which may have emerged, consciously or unconsciously, and to discuss their dynamics.

The *degree centrality* and the *betweenness centrality* indicators were applied to Nodes (R&I organisations, including both research centres and agri-food firms) and Edges were weighed according to the number of projects each couple of organisations collaborated on. Moreover, macro-descriptors of the like of the *average path length*, the *clustering coefficient* and the *degree distribution* were chosen to analyse the whole network. The Gephi Tools open source software package was used both to measure the indicators and to draw the network diagrams, based on Fruchterman-Reingold layout algorithms [1].

Geospatial data analysis was performed with Kepler.gl, a high-performance web-based application for visual exploration of large-scale geolocation data sets [2, 31]. In Fig. 3 we provide a step-by-step visual representation of the research process.

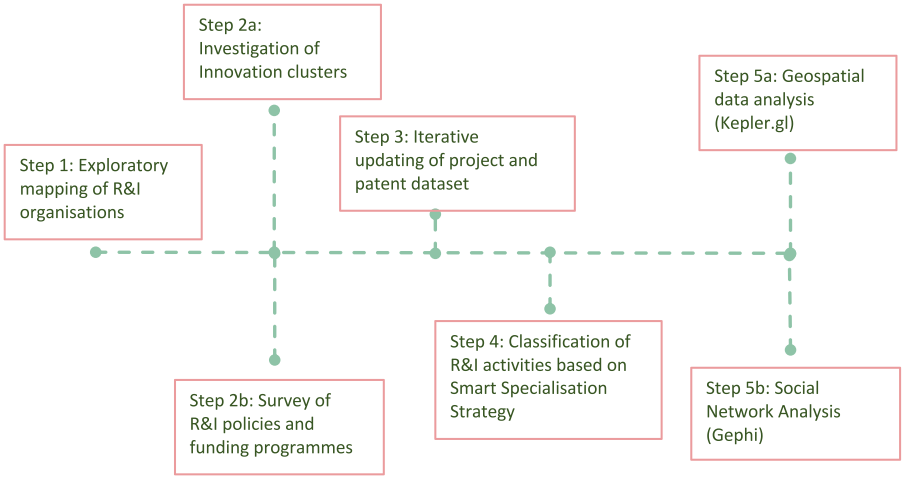

Fig. 3. The main steps in the research workflow.

4 Results

Following a survey of R&I activity, 145 projects (including permanent research facilities that focus on the agri-food sector) and 17 patents were identified. These are listed in Table 1, as sorted according to the main research organisation (out of the total 11) that was involved in the activity.

The full dataset allows a breakdown of the R&I activity carried out at each organisation into their internal departments and centres. Most R&I organisations are public bodies, state-controlled or publicly funded hybrid organisations, with a few exceptions. Within larger organisations, it is interesting to note that agri-food related R&I activity sometimes involves units that focus on different areas, such as information technology and health, thus signalling an interdisciplinary approach.

Among the Spin-offs that carry out applied research in the agri-food sector, Sinagri (University of Bari) and Innovative Solution (Polytechnic University of Bari) are those that are currently active in the largest number of projects. The latter also developed a relevant patent.

R&I outputs were subsequently sorted according to the main categories of thematic links, to track trends and specialisation patterns. With respect to value chains, Fig. 4 concerns both projects and patents: beside the main value chains of interest in the region, Labelling and Logistics have been singled out from other cross-cutting topics (which still account for 35% of the total activity), because of their relevance to territorial cooperation and market internationalisation.

Fruit and vegetables (15%), olive oil (13%) and wine (11%) are the most represented value chains, with most activities dealing with productivity enhancement or quality control. Most of the 17 patents concern the processing of cereals and flours to produce low-gluten pasta (23%), the development of a novel biodegradable-food-packaging material (18%), and innovative methods to produce canned fruit (18%).

Table 1. Research and innovation activity in Puglia (2010–2019) in the agri-food sector, with respect to projects and patents, sorted by the leading research organisation.

Research Organisation	Units - Departments, laboratories, Spin-offs, *etc.* (n.)	Projects (n.)	Patents (n.)
University of Foggia	34	44	9
University of Bari	20	50	5
University of Salento	11	22	1
Polytechnic University of Bari	4	13	1
Council for Agricultural Research and Economics (CREA)	8	30	0
National Research Council (CNR)	16	45	1
Animal Health Research Institute of Puglia and Basilicata (IZSPB)	4	11	0
CIHEAM/IAMB - Mediterranean Agronomic Institute of Bari	1	19	0
CMCC Foundation - Euro-Mediterranean Research Centre on Climate Change	1	1	0
"Giovanni Basile Caramia" Centre for research, development and training in agriculture	1	8	0
Bonassisa Lab	1	3	0
Total	101	246*	17

*This count is redundant, when compared to the previously mentioned figure of 145 projects, because some projects were carried out by two or more partners.

As for the priorities identified by the Region's Smart Specialisation Strategy – adopted in the wake of the EU 2020 smart, sustainable and inclusive agenda – only *Sustainable Manufacturing* and *Human and Environmental Health* were significantly represented in both projects (around 40% each) and patents (around 50% each), while *Digital, creative and inclusive communities* were only relevant to 17% of projects.

The concentration of patents in a few areas is also observed when Key Enabling Technologies are adopted as categorisation principles (Fig. 5), although in this case only one category is prevalent in both projects and patents (*Industrial Biotechnology*),

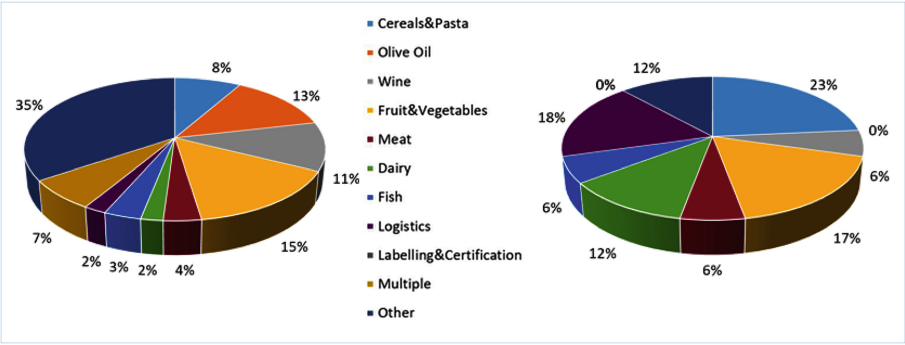

Fig. 4. R&I activity in the agri-food sector in Puglia (2010–19), sorted according to value chains. Projects on the left, Patents on the right.



Fig. 5. R&I activity in the agri-food sector in Puglia (2010–19), sorted according to Key Enabling Technologies. Projects on the left, Patents on the right.

whereas *Advanced Materials* (for projects) and *Nanotechnology* (for patents) proved to be the dominant categories accounting, respectively, for 41% and 65% of the activities.

4.1 The Shaping of Research and Innovation Networks

Partnerships are key to R&I activity, although only one third of the surveyed projects involved two or more partners. Based on this subset, a major difference may be appreciated, that is, the share of projects focusing on no particular value chain is significantly lesser, whereas the breakdown among the other items is similar in proportion (Fig. 6).

The most remarkable difference in the distribution of collaborative projects over smart specialisation priorities, when compared to the whole sample, concerns a significant increase in the share of *Sustainable Manufacturing* (more than 30%) to the detriment of *Human and Environmental Health.* Similar trends, yet of a lesser magnitude, may be observed for Key Enabling Technologies – with *Micro/Nano-electronics* and *Advanced Materials* increasing, while *Nanotechnology* and *Industrial Biotechnology* are less represented in collaborative projects. Most of the partnerships sought to develop innovative technologies and materials aimed at boosting either resource-efficiency, or the recycle and reuse of waste and by-products.

Turning to SNA for a quantitative analysis, an overall network of 87 partners was detected – 47 of which were departments, laboratories or Spin-offs affiliated to any of

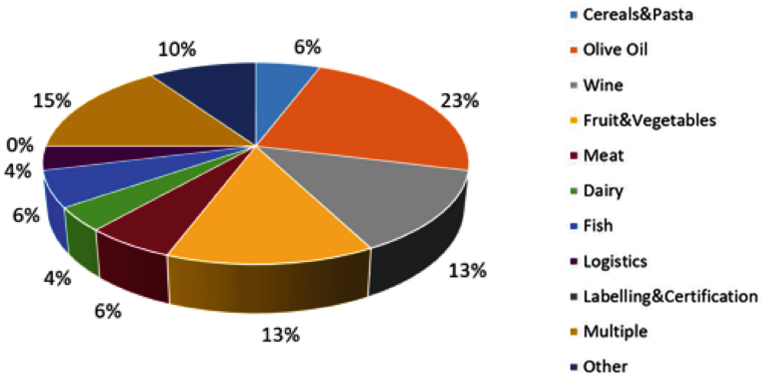

Fig. 6. R&I projects in the agri-food sector in Puglia (2010–19), carried out by partnerships of two or more organisations, and sorted according to value chains. *Cfr*. Fig. 4.

the 11 R&I organisations listed in Table 1, while 40 were agri-food firms. Out of the total 52 collaborative projects, 23 involved 5 or more partners (with two projects gathering 11 partners each), while four or less partners worked together in 29 initiatives. Partnerships of 2 or 3 members were the most frequent cases, and all 2-partner projects involved only research organisations.

A visual representation of the overall R&I network is provided in Fig. 7, using the *degree centrality indicator* and showing weighted edges, based on the Fruchterman-Reingold Layout algorithms. Beside the apparent centrality of about 10 highly connected organisations – in equal share, research centres (among which, four are hyper-connected to each other) and agri-food firms – there appear to be two relatively homogenous network components with gradually decreasing interconnectedness. A negligible number of nodes, mostly research centres, are peripheral or relatively isolated, since the edges of lower-degree nodes tend to spread over large areas of the network.

The centrality of the core component is reinforced by the observation that the involved nodes (all representing research organisations) have the highest values for both degree and node strength (since edges are weighted according to the number of projects each couple of organisations is collaborating on), and also relatively high values of *betweenness centrality*.

4.2 The Spatial Dimension of Innovation Networks

The contribution of R&I to territorialisation processes was first investigated by searching for the role of agri-food clusters, established under a regional law: 16 projects fall within the Regional Agri-food Cluster-D.A.RE., which therefore appears to play a key role in fostering R&I in its target thematic area, while only one project involves the Plant nursery and Flower growing Cluster and none concerns the other two clusters ("Jonico Salentino" and "Terre Federiciane" Agri-food clusters), despite the affiliation of both agri-food business and research organisations.

A further attempt to unravel the spatial links of agri-food R&I activity across the Puglia region moved from mapping projects and patents onto the location of the

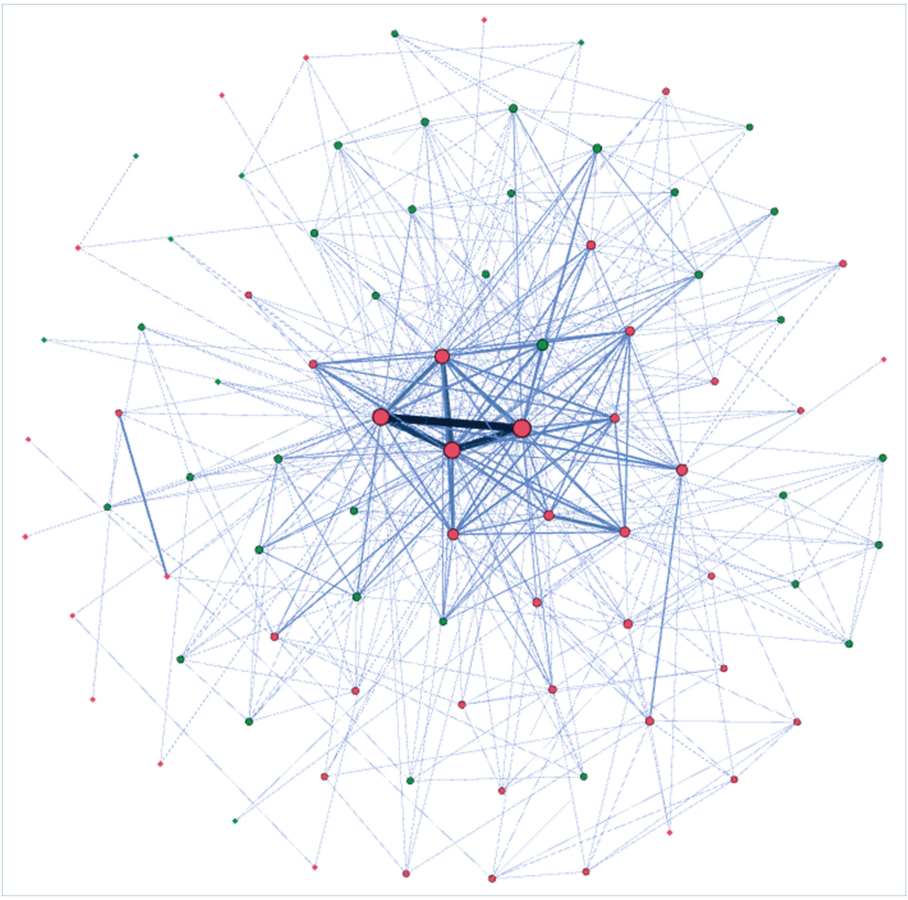

Fig. 7. The network of collaborative R&I projects diagram, based on the *degree centrality* indicator, weighted edges and Fruchter-man-Reingold Layout algorithms. Nodes representing research centres are red, agri-food business green. (Color figure online)

intermediate-level unit within the relevant organisations and drawing a corresponding topographic network accordingly. A very preliminary outcome of such efforts, supported by the Kepler.gl web application, is included in Fig. 8.

4.3 The Role of Agri-Food Business in R&I Networking

A focus on the involvement of agri-food firms in R&I activity revealed contrasting trends. On the one hand, there are very few firms engaging in R&I activity (40 out of a total 80,000+ in the region), and yet most of them participated in at least five projects, thus suggesting that they have been building up innovation capacity over time. Moreover, although their average *betweenness centrality* is lower, they don't show the polarisation that may be observed for research organisations, whose average values are driven by a few very high values. When the analysis is limited to the sub-network based on those

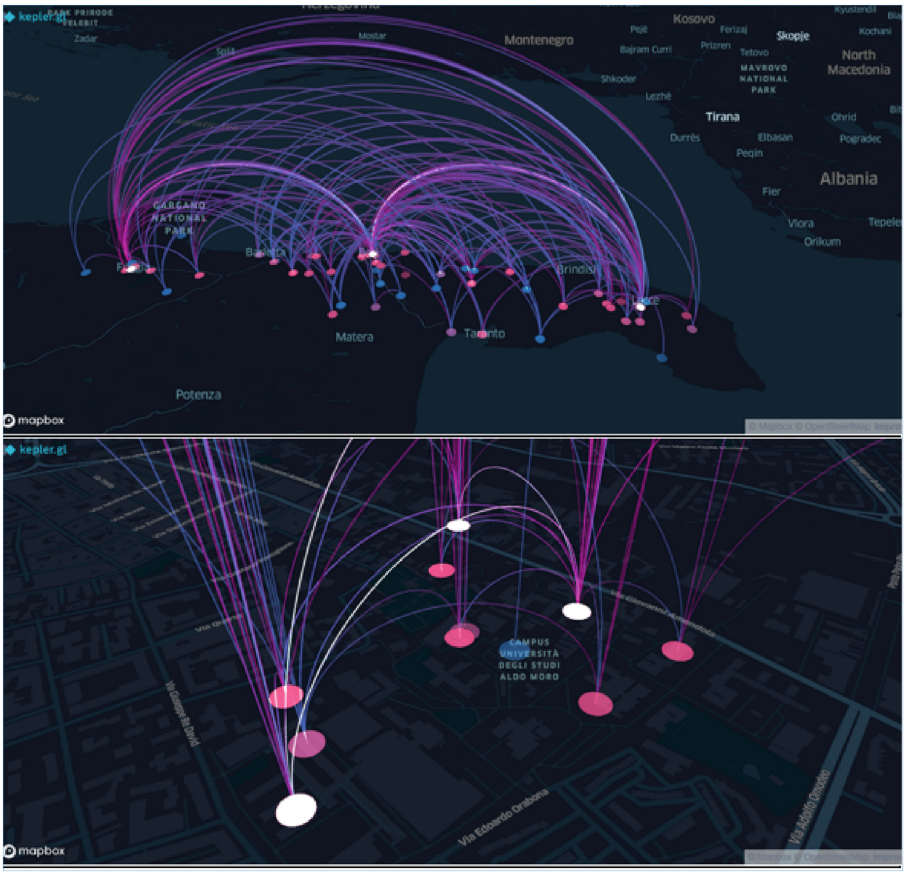

Fig. 8. A spatial visualisation of the R&I network in Puglia, built with Kepler.gl: in the top panel, the whole network; in the bottom panel, a dense cluster of research centres (in Bari).

R&I projects that involve at least one firm, the number of active research organisations drops from 47 to 25 (since 22 research centres only collaborate with other research organisations) and a relatively more fragmented network structure emerges (Fig. 9), as corroborated by the moderately higher value of *average path length* (2.47 vs 2.17) and the considerably lower value for the *clustering coefficient* (0.48 vs 0.83).

A core component is still manifest, although it now appears to include both research centres and agri-food firms, in almost equal share. Two smaller components are visible on the right side, loosely connected to the core, and only connected to each other through the intermediation of two research centres, which therefore have a relatively high betweenness centrality. It is also worth pointing to an organisation that has been grouped under the agri-food firms though in fact being a consultancy (Agriplan): it shows as high degree and centrality values as those of the core research centres.

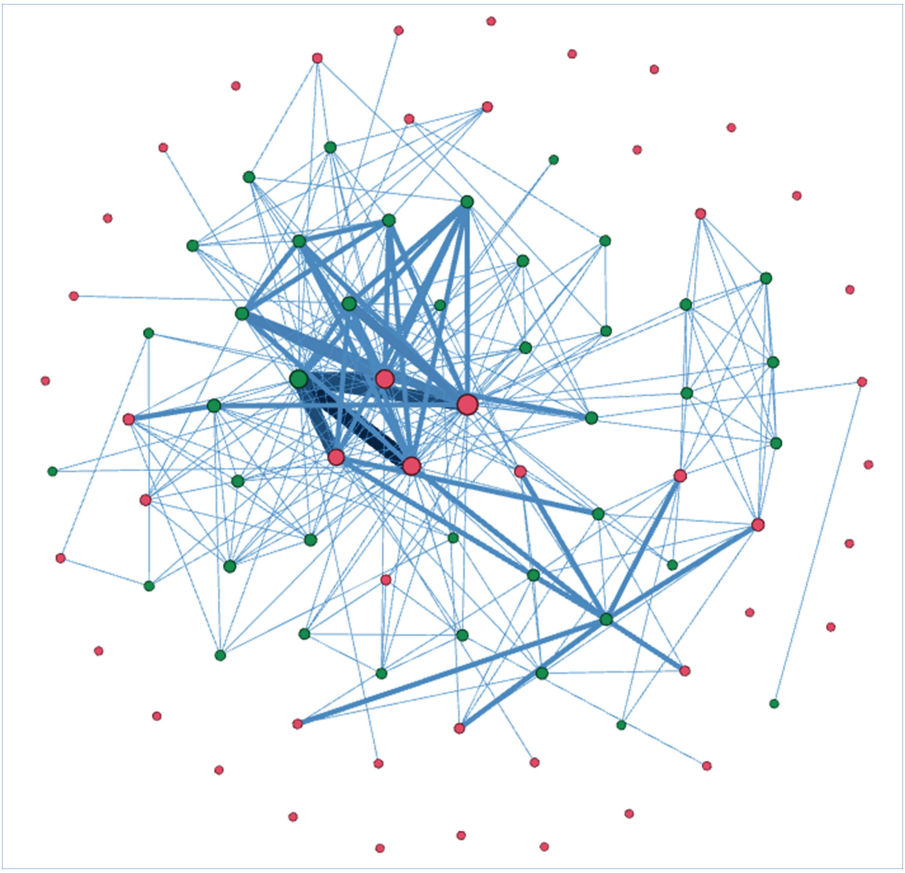

Fig. 9. The R&I sub-network of collaborative projects in Puglia that involve at least one agri-food business. The same methodological remarks as in Fig. 7 apply. Nodes representing research centres are red, agri-food business green. (Color figure online)

5 Discussion and Conclusions

This paper discusses the potential role of agri-food R&I activity in contributing to sustainable local development, by bridging smart specialisation strategies and agriculture and rural development policy. A focus on open innovation, understood as the co-creation of knowledge and innovative products, services or policies within flexible networks of research institutes, agri-food firms, civil society organisations and public-sector bodies [5, 6].

An exploratory study was carried out concerning recent (2010–19) agri-food R&I activity in Puglia (Italy), yielding a dataset that comprise 145 projects and 17 patents – developed by 47 research centres (affiliated to any of 11 research institutions) and 40 agri-food enterprises.

The preliminary results show that R&I activity in the agri-food sector in Puglia tend to focus on the main value chains (Fruit and vegetables, olive oil and wine), by aiming

for some form of sustainable agricultural intensification [22]. Sustainable Manufacturing and Human and Environmental Health have an almost equal prevalence – which translate into projects and patents that deal almost exclusively with Industrial Biotechnology, Advanced Materials and Nanotechnology. It is not clear, however, whether these potentially ambivalent smart specialisation priorities are more likely to secure synergies or rather to bring about controversy [18].

As for paradigm shifts in R&I activity, there is limited evidence that open innovation is playing any significant role, save for a relatively minor yet apparently dynamic involvement of agri-food enterprises. The emerging networks, however, still seem to be centred around a few highly connected intermediate nodes – mainly research centres but some agri-food firms too are represented – in what verges on *small-world* models [17] which, rather than reflecting the dynamics of alternative food networks [3] could point to the persistence of mostly uncharted R&I directions and largely untapped relational resources in the regional agri-food sector. Further research is needed to investigate whether this innovation might be thwarted by better positioned partners [9].

The work fell short in addressing the links between R&I activity in the agri-food sector and sustainable local development, especially when it came to discussing their influence on territorialisation processes. To that end, since most projects and patents concerned food processing technology or cross-cutting issues that are relevant to different value chains, the chosen approach of matching agricultural land covers to specific value chains did not deliver on the goal of identifying any specific geographical structure, beyond a self-evident concentration of research institutes and facilities.

The limitations of the study include, among others, the lack of a comprehensive review of national funding programmes as well as of small-scale, start-up business [8]. However, this weakness is likely to be affected by farther-reaching friction between the dominant industry-driven and knowledge-intensive smart specialisations, and place-based innovation patterns that tap into the intangible potential of social and relational capital [4].

Further developments of this research may, therefore, aim at tracing innovation practice-in-action in the agri-food sector in a transboundary context, within the territorial cooperation networks whose innovation capacity the Innonets project is expected to enhance.

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