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Territorial innovation systems: a study of the factors connected to local competitiveness.

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Indice

1. Introduction

1. Introduction

Regional innovation systems (RISs) and local innovation systems (LISs) have recently received increasing attention due to their relevance in academia and public policy. The literature differentiates the nature of the territorial innovation systems according to diverse perspectives. For instance, Braczyk et al. (1998), Asheim et al. (2011) and Kaihua and Mingting (2014) investigated the innovation systems concerning regions, while Simmie (2001) referred to the most innovative cities. Specific and possible characteristics of LISs have been analysed - among others - by Martin and Simmie (2008) and Ferretti and Parmentola (2015). These latter authors examined LISs considering (1) the potential network of innovative firms, (2) research entities that generate scientific knowledge, (3) infrastructure provisions, (4) cooperation mechanisms among all the factors which increase within the same geographic proximity. Usually, innovation system literature emphasises the performance of the various sites and analyses how these areas utilise the available assets (Zabala-Iturriagagoitia et al., 2007; Avilés-Sacoto et al., 2020). Specialised skills, research establishments, sharing common social and cultural values, etc., can contribute to the firm's performance and regional competitiveness.

In places where localised capabilities and skills exist, local development and competitiveness increase. Concepts of learning regions, industrial districts, local productive systems represent several examples of study experiences using a similar perspective. Nevertheless, since the research question about how innovation can be correctly measured among several territorial districts is still open, the close relationship between the perspectives connected to the innovation evaluation and the LISs requires a more thorough study. In the authors' opinion, the investigation proposed in the current report contributes to this debate attempting to examine the assessment of the LIS specifications through a specific technique. The theoretical model reassesses the assumptions discussed by Po et al. (2009) by employing the data envelopment analysis (DEA) production function to cluster well-defined homogenous and comparable innovative indicators. These indicators have been selected from an accurate literature review. Different results connected to the usage of several indicators proposed in the current report have already been discussed in Cataldo et al. (2021). However, this latter research paper involves a diverse model (the structural equation model - SEM - partial least squares - PLS - path modeling -PM). As for the remaining content of this article, it is structured as follows. Section 2 refers to the background and literature review. The theoretical model is introduced in section 3. Section 4 presents the discussion, while section 5 concludes with future research.

"Regional innovation systems (RISs) and local innovation systems (LISs) have recently received increasing attention due to their relevance in academia and public policy.

2. Background and literature review

2. 1 Innovation

Concerning the broad definition of innovation proposed in the literature on territorial innovation systems, Roberts (1988, p. 13) considered innovation as an "invention plus exploitation", including the implementation of a new (or significantly improved) product, process (or service) and the commercialisation of innovation. Similarly, Boons and Lüdeke-Freund (2013) highlighted that innovation is often distinguished from an invention by the additional condition of a successful market introduction. The fourth edition of the Oslo Manual (OECD, 2018A) presented a detailed framework to classify the innovation outcomes in terms of three different outlooks: the type of technology (process/product), the level of novelty (innovation in the firm or the market), and its commercial success. The OECD handbook also proposed a detailed updated guideline focused on measuring innovation in the business sector. Despite the debate on the meaning of innovation, its significant contribution to economic growth has been well established in economic literature.

Supporting innovation represents one of the seventeen sustainable development goals (SDGs) of the 2030 agenda. Several authors, such as Becheikh et al. (2006), Freeman and Soete (2009), Evanschitzky et al. (2012) and Van Holt et al. (2020), broadly discussed which dimensions should be used to evaluate innovation.

The European Innovation Scoreboard (EIS; European Commission, 2020) is the most commonly used index to estimate the innovation in EU area, and European Regional Innovation Scoreboard (ERIS; European Commission, 2019) represents the index fixed for the regional area, considering a restricted number of dimensions.

Among others, Jaffe (1989) referred to patent statistics to involve the universities' outcome, while Griliches (1984; 1990) added to patent data the research & development expenditures (R&D). Since these indicators presented several criticisms, Dodgson and Hinze (2000), Becheikh et al. (2006) and Dewangan and Godse (2014) discussed several proxies distinguishing several kinds of indicators to address these issues. Among others, Rothwell (1992), Hagedoorn and Cloodt (2003), Smith (2005), Gössling and Rutten (2007), Nelson (2009) and Makkonen and van der Have (2013) presented further advancements. Table 1 summarises selected research papers showing different innovative dimensions related to the organisation structure, financial features at the firm level, and market and contextual network dimensions (Dziallas and Blind, 2019).

Table 1 - Research papers connected to different innovative indicators.

Authors	Indicators
Graner and Mißler-Behr, 2013 Hittmar et al., 2015	Amount of time managers spent with innovations compared to normal tasks
Hittmar et al., 2015	Number of newly created innovative opportunities
Frey et al., 2013 Slater et al., 2014 De Fuentes et al., 2015	Size of the company The geographic location of the company
Dewangan and Godse, 2014 De Medeiros et al., 2014 Cavdar and Aydin, 2015 De Fuentes et al., 2015	Average expenditure per selected ideas Percentage of sales related to new projects Share of research budget from total company budget Innovation expenditure
Ivanova and Avasilcăi, 2014	Competitor analysis (monitoring of competitors)
Dewangan and Godse, 2014 Fleuren et al., 2014	Customer satisfaction
Caird et al., 2013 De Medeiros et al., 2014 Carayannis, Grigoroudis, and Goletsis, 2016 Avilés-Sacoto et al., 2020	Technology transfer activities with research institutions R&D alliances
Al-Mubaraki et al., 2015	Number of innovative businesses New venture start-ups

Concerning the methods used to investigate innovation, Dziallas and Blind (2019) noted that regression analysis is applied most frequently (at 27%) in comparison with the other techniques considered in their analysis, while different procedures refer to descriptive approaches, correlation analysis, factor analysis (FA), ordinary least squares regression (REG), structural equation model (SEM), etc. These methods are used individually or jointly to investigate the LIS. In addition to these approaches, Cruz-Cázares et al. (2013), Carayannis et al. (2015; 2016) and Avilés-Sacoto et al. (2020) added the DEA as a well-established technique to evaluate the LIS. Table 2 reviews several examples of LIS's specific techniques and their indicators.

Table 2 - Several examples of LIS's specific techniques and the indicators connected to them.

Authors	Methods	Indicators involved (inputs and outputs; dependent variable; etc.)
Avilés-Sacoto et al., 2020	DEA	Inputs (1st and 2nd stages): R&D Employees; R&D Investment; Foreign Direct Investment: intermediate outputs; etc. Outputs (1st and 2nd stages): Nr. of R&D Projects; Sales; Patents and Trademarks; Total Production. etc.
Buesa, M. et al., 2010.	FA and REG	Patent data.
Carayannis, et al., 2015	DEA	Input: Graduates in tertiary education; Involvement in lifelong learning; R&D ; Patent applications; SMEs collaborating; etc. Outputs: High Tech Exports.; License and patent revenues from abroad; Sales; Number of trademark applications in national offices.
Guan and Chen, 2012	DEA	Inputs: Number of patents granted; New doctorate graduates; Number of full-time equivalent scientists and engineers; Incremental R&D expenditure funding innovation activities; etc. Outputs: International scientific papers; the added value of industries; etc.
Kaasa, 2009	PCA - SEM	Principal components analysis' results (20 dimensions).
Pan et al., 2010	DEA	Inputs: Total public expenditure on education; Imports of goods and commercial services; R&D; Direct investment stocks abroad; Total R&D personnel. Outputs: Scientific articles published; Number of patents; etc.
Sharma and Thomas , 2008	DEA	Inputs: GDP per capita; GDP expenditure on research; Researchers per population; Outputs: Number of patents and publications
Zabala-Iturriagagoitia et al., 2007	DEA	Inputs: Higher Education; Participation in lifelong learning; Medium-high tech employment in manufacturing; Public and Private R&D; etc. Outputs: Regional GDP per capita

2.
Background and literature review

2.2 Territorial features and LIS

The relevance of the territorial level in investigating innovation has been recognised by - among others – Edquist (1997), Bottazzi and Peri (2003), Moulaert and Sekia (2003), Asheim et al. (2011), Moura et al. (2017), Carayannis et al. (2018) and Hauser et al. (2018). European Commission (2019) also emphasised that densely populated areas have a greater propensity for innovation. The local business environment's significant contribution has been broadly discussed by Asheim and Coenen (2006), who highlighted that the partnership constitutes a key feature of LISs. Lee and Park (2006) focused on (1) the financial support from governments to R&D investment. The interactions among university-industry-government has also been discussed by Leydesdorff and Etzkowitz (1996), Etzkowitz and Leydesdorff (2000), Audretsch and Lehmann (2005), Cooke (2005) D'Este and Patel (2007), Leydesdorff and Zawdie (2010) and Predazzi (2012) Callaert et al. (2015), and Zhao et al. (2015). Cooke and Leydesdorff (2006), Rinkinen et al. (2016) and Farinha et al. (2018) emphasised that innovation policies need to enhance specific firm organisations, human capital and social sustainability features.

2.3 Innovative NACE codes

As mentioned above, the OECD (2018A) proposed several recommendations for evaluating innovation since international evaluations of innovation structures involve a heterogeneous structure, which requires that definite NACE codes be considered to perform each empirical analysis. Several additional specifications refer to the economic activities that are not recommended for innovation investigation in the business sector, also because the OECD (2018A) Manual highlighted that the international standardisation of business register in some countries is still inadequate. For instance, several NACE sectors (such as sections A — Agriculture, forestry and fishing, I—Accommodation and food services activities, N—Administrative and support activities) present significant criticisms in several EU countries; furthermore, diverse activities - for instance, human health and social work, arts, entertainment (and recreation) and non-profit institutions - provide their services in many countries. Consequently, they are excluded from international comparisons. The authors assume that the present report offers a statistical model that can also be extended to international comparisons. According to this assumption, well-defined NACE categories—strongly linked to innovation—have been considered. The (active) firms involved in the model are selected fixing primary (and secondary) NACE codes quoted in Table 3.

Table 3 - NACE codes strictly dependent on innovation

Section	Division	Section	Division
B	05-09	H	49-53
C	10-33	J	58-63
D	35	K	64-66
E	36-39	L	68
F	41-43	M	69-75
G	45-47		

Source: Eurostat (2018); OECD (2018)

In Italy, the innovative SMEs different from the codes cited in Table 1 are very few since they account for less than 3% of total firms. Therefore, this finding allows the authors to consider the aforementioned NACE codes in this report. In addition, although all firms can be innovative and should be included in the business innovation analysis, innovation activity is generally managed differently in larger firms than SMEs. Consequently, in the current work, authors consider an additional criterion that refers to the firm dimension, consistently with the corresponding DL 3/2015 SMEs definition.

3. Theoretical model

Following Po et al. (2009), the basic idea is to use production functions to cluster production data. On the one hand, cluster analysis represents a multivariate statistical model for organising similar data set groups in the same cluster and different groups in distinct clusters. This method represents a data-driven exploratory approach for forming data groups by considering the proximity and homogeneity in feature space. Clustering methods can be classified according to several approaches (hierarchical clustering, mixture-model clustering, etc.) that involve algorithms that minimise total dissimilarity in the conventional model (such as the k-means, fuzzy c-means, etc.). On the other hand, the DEA, initially proposed by Charnes et al. (1978), considers a non-parametric method to estimate the production frontiers, and Po et al. (2009) considered each piecewise frontier as one cluster of production functions that can be considered as a base to cluster production data. Consistent with this perspective, the present paper proposes a similar approach in order to define LISs throughout the cluster analysis. In more detail, for each territorial district (the DMU), it is possible to know the cluster that it belongs to and the production function type that it involves. In the authors'opinion, managerial decision-making needs to evaluate the changes required in LISs combining input/output resources so that each LIS can be re-classified. Among others, Bouguettaya et al. (2015) highlighted that cluster analysis is an important means of

$$\hat{\theta}_i^{FDH} = \min_{j=1,\dots,N \mid y_{lj} \geq y_{li}\ \forall\ l} \left\{ \max_{k=1,\dots,K} \left(\frac{x_{kj}}{x_{ki}} \right) \right\} \quad (1)$$

If $\min_{j \epsilon B_i}$ is considered, B_i represents the set of peers that satisfy the condition $y_{lj} \geq y_{li}\ \forall l$. FDH compares each firm (*i=1,…..N*) with all other DMUs (*j=1,…..N*), considering a set of inputs $(x_{i1}, \dots. x_{iK})$ and a set of outputs $(y_{i1}, \dots. y_{iL})$. $\hat{\theta}_i^{FDH}$ is calculated considering the DMU that exhibits minimum input consumption. Order-*m* score is obtained as the average of pseudo-FDH efficiencies, as follows:

$$\hat{\theta}_{mi}^{OM} = \frac{1}{D} \sum_{d=1}^{D} \hat{\theta}_{mi}^{\widetilde{FDH}_d} \quad (2)$$

$\hat{\theta}_{mi}^{\widetilde{FDH}_d}$ characterises the pseudo-FDH score which is obtained using a sample of *m* peers randomly drawn with a replacement, and this procedure is repeated *D* times. The order-*m* efficiency allows for scores that may exceed the value of one of DMUs located beyond the estimated frontier. The order-*m* requires the choice of values for two parameters, *D* and *m* (for *m*→ ∞ order-*m* coincides with FDH).

Compared to the order-*m*, the order-*α* does not involve a resampling procedure and generalises the (input-oriented) FDH procedure, as the following equation expresses:

$$\hat{\theta}_{\alpha i}^{OA_{input}} = P_{(100-\alpha)\, j=1,\dots,N|y_{lj}\geq y_{li}\,\forall\, l}\left\{\max_{k=1,\dots,K}\left(\frac{x_{kj}}{x_{ki}}\right)\right\} \quad (3)$$

When $\alpha = 100$, order-*α* coincides with the FDH. Among others, see Silva et al. (2016) for specific values for *m* and for *α*.

3.1 Indicators involved in the model

The proposed approach is based on several dimensions, and more details about codes, variable definitions and sources are provided in Table 4.

Table 4 - Manifest variable names and sources

Manifest variable names	Sources
Potential innovative SMEs	I
Innovative SMEs	I
Innovative start-up	I
Spin-off	IV
R&D expenditure business sector	II
Product or process innovators	II
SMEs innovating in-house	II
Innovative SMEs collaborating with others	II
PCT patent applications	II
Trademark applications	II
Annual GDP growth rate	III
Neet (15-29)	III
Mortality rate (leading causes of death) [30-69]	III
Education and training activities during the last 4 weeks [percentage participation rate]	III
Undeclared workers	III
Employment rate (15-64)	III

Sources: - I Bureau van Dijk and OECD (2018B); II-Regional Innovation Index; III-ASviS; IV - https://www.spinoffitalia.it/. Full description of each variable and more details about the sources are available on request.

Special prominence has to be devoted to innovative SMEs according to the Decree Law – DL - 3/2015 (further updated by the DL 135/2018). These firms might be recorded in the innovative SMEs special unit of the business register of the Italian Chamber of Commerce. The innovative SMEs could benefit from most of the support measurements targeted only at the innovative start-ups according to DL 179/2012 (the Italian Start-up Act). See Lukkarinen et al. (2016), OECD (2018B), MISE (2020) and Cataldo et al. (2021b) for an extensive description of these features.

As a consequence of the Covid-19 pandemic, among the measures targeted to support the Italian economy, the DL no. 34/2021 (the "Relaunch Decree") has introduced several additional facilities for start-ups, innovative SMEs and, more generally, in the research and technological development sector, as follows:

- Supplementary financial resources to the 'Venture Capital Support Fund' (Law 145/2018) to support investments in the capital of start-ups and innovative SMEs.
- Additional incentives for investors in start-ups or innovative SMEs (gross tax deduction on personal income equal to 50% of the amount invested by the taxpayer in the share capital of one or more innovative start-ups or SMEs).
- Major tax credit in research and development
- Concerning specifically the innovative start-ups: fewer restrictions for two-year visas for non-EU citizens (Investors Visa for Italy) who make investments; introduction of a 'legal equivalence' of the innovative start-ups to universities (and research entities) in the 'R&D extra muros' contracts; extension of the term of stay in the special section of the business register of the Italian Chamber of Commerce.

Moreover, in this approach, one could consider - in addition to innovative SMEs and several other dimensions - a proxy of the potentially innovative SMEs to assess the effect of this latter indicator on clustering the LIS. In the authors' opinion, potentially innovative SMEs represent those firms that could become innovative but cannot because they do not have all the requirements. To estimate this proxy, the authors assume that certain budget items are crucial to counting in the innovative SMEs special section. The usage of this dimension has been extensively discussed in Cataldo et al. (2021a; 2021b). Overall, specific thresholds can be used to select the potential innovative SMEs, a set of limited companies that can be the actors of empirical analysis. Data from different sources, namely the Italian Alliance for Sustainable Development (ASviS), ISTAT (2019), RIS and Bureau van Dijk (Amadeus) can be considered. For some variables, the lack of updated data could be a problem; in this case the previous year could be taken as a reference. In this approach, a weakness might derive, for instance, from the NACE classification of the firms involved, which may change over several years, and from several firms that present a higher degree of informality (thus representing possible candidates to be missing from statistical business registers, especially in countries in earlier stages of development).

4. Discussion

4. Discussion

The innovation capacity for a specific firm depends on the innovation system, which depends on the characteristics of the networks that companies adopt to access knowledge and facilitate innovation. Company size also has a significant relevance on its knowledge network, and the ongoing dynamic interactions in networks may represent an essential source of innovation. Overall, the firms that devote most in the development of their inter-firm knowledge networks (alongside other external knowledge networks) seem to return with higher levels of innovation. In this scenario, LISs derive from an interaction of specific social, cultural, economic and political environment and contain factors and relations that interact with the production, dissemination and application of new knowledge. Beyond clusters and competitiveness, the LIS might constitute one of the most important underlying aspects of economic growth; the intensity of the interactions between R&D in the public and private sectors - in addition to the territorial district features - influence the LISs' performances and its capacity to convert local academic research into local commercial innovation is a determining factor to the competitiveness of the LIS in the globalised knowledge economy. In the same way, the network systems offer an important source of innovation with a strong connection to LIS performances.

5. Future Work

5. Future work

These significant findings require extreme attention in examining the links among the LIS and its indicators. Possible awareness might be relevant from a policy point of view since the subject of the study is the examination of the effects that may contribute to the LIS structure. In future investigations - the number of indicators and the contextual factors may also be extended, and additional considerations refer to the fact that it is crucial to point out that the proposed DEA-based clustering algorithm can be further investigated.

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