Regions, innovation systems, and the North-South divide in Italy

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Abstract

Innovation systems are not bound by administrative or political boundaries. Using information theory, we measure innovation-systemness as synergy among size-classes, postal addresses, and technological classes (*NACE*-codes) of firm-level data collected by Statistics Italy at different scales. Italy is organized in twenty regions, but there is also a traditional divide between the North and the South of the country. At which levels is how much innovation-systemness indicated? The greatest synergy is retrieved by considering the country in terms of Northern and Southern Italy as two sub-systems, with Tuscany included as part of Northern Italy. We suggest that separate innovation strategies could be developed for these two parts of the country. The current focus on regions for innovation policies may to some extent be an artifact of the statistics and EU policies. In terms of sectors, both medium- and high-tech manufacturing (MHTM) and knowledge-intensive services (KIS) are proportionally integrated in the various regions

Keywords

Innovation systems; Innovation policies; Triple helix; Synergy; Regions; Administrative boundaries; Economic divide; Italy.

1. Introduction

The concept of national innovation systems was first proposed by **Freeman** (1987) after a visit to Japan. In the years thereafter, **Lundvall** (1993) and **Nelson** (1993) provided two collections of comparative studies of innovation systems among nations. However, the emphasis on “national” more or less provoked the question of whether innovation systems might also be regional. On the one side, regions such as Catalonia, Flanders, and Wales have autonomous aspirations. At the level of the European Union, on the other side, the metaphor of an emerging “knowledge-based economy” rapidly became more popular than a focus on nations (**Foray**; **Lundvall**, 1996; *Commission of the European Community*, 2000).

Both the EU and the *OECD* provide incentives for organizing regional innovation agencies and programs. Among other things, the *OECD* reviews regional innovation policies with the objective of providing policy recommendations (e.g., *OECD*, 2009). In innovation studies and economic geography, it is increasingly assumed that regions

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(including metropolitan regions) are the appropriate units of analysis for studying the transition to a knowledge-based economy (e.g., **Braczyk**; **Cooke**; **Heidenreich**, 1998; **Cooke**, 2002; **Feldman**; **Storper**, 2016; **Florida**, 2002; **Storper**; **Kemeny**; **Makarem**; **Osman**, 2015).

For the purpose of implementing innovation policies at the appropriate level, it is important to understand the complexity and boundaries of innovation systems. **Griliches** (1994) noted that the use of administrative units in statistics can be a data constraint for innovation studies and also for innovation policies. For example, innovation may depend on interactions and infrastructures that do not match regional and national boundaries (**Carlsson**; **Stankiewicz**, 1991). Sectorial innovation systems (e.g., oil refinery; biotechnology) are in important respects organized internationally (**Carlsson**, 2006; 2013).

Innovation may depend on interactions and infrastructures that do not match regional and national boundaries

Malerba (1993, at p. 230) argued that “not one, but two innovation systems are present in Italy:”

- The first one is a “core R&D system” that operates at the national level through systematic cooperation between large firms with industrial laboratories, small high-tech firms, universities, public research institutes, and the national government.
- The second innovation system would be a “small-firms network” composed of a plurality of small- and medium-sized firms that cooperate intensively at the local level, often within industrial districts, and generate incremental innovation through learning-by-doing.

More generally, it has been shown that firms interact with non-regional universities if the knowledge and skills required are not available within the region (**Asheim**; **Coenen**, 2006; **Fritsch**; **Schwirten**, 1999) or when they are seeking higher-quality collaboration partners at the international level (**D’Este**; **Iammarino**, 2010; **Laursen**; **Reichstein**; **Salter**, 2011).

Notwithstanding these international ramifications, one can expect the coherence of an innovation system to be a mixture of both national and regional aspects given the organization of the political systems. The research question then becomes: how much innovation-systemness is generated at the various levels? Is this innovation-systemness distributed across regions or specialized in specific regions? The synergy measure used in this paper enables us to address these questions empirically. We focus on Italy as a challenging and exemplary case: to what extent and at which level is innovation-systemness indicated? Can the regions carry the function of “regional innovation organizers” (**Etzkowitz**; **Klofsten**, 2005)? In other words, we test whether regional innovation systems are indicated using entropy statistics.

2. The Italian innovation system

Italy was shaped as a nation state in the period 1848-1870. During the Second War of Independence (1859-1861), the northern part was unified under the leadership of the Kingdom of Piemonte (Turin), and the southern part —the Kingdom of the Two Sicilies (with Naples as capital)— was conquered by Garibaldi. Central Italy, which until then had been the Papal State, was invaded by Italy in 1870 and thereafter Rome became the capital of the nation. The division into three parts —Northern, Central, and Southern Italy— has, however, remained important; it is commonly used for analytical and policy purposes. However, the North/South divide is also a common terminology in political discourse: the “questione meridionale” or the Southern Question. In short, the North and the South have different cultural traditions and marked differences in GDP per capita, composition of economic activities, and employment indicators.

At a lower level of aggregation, the country is administrated in terms of twenty regions of which five have a special status. Among these, Valle d’Aosta is an autonomous region, in which French functions as a second language. Alto Adige (also known as Süd-Tirol) is an autonomous province of Trentino-Alto Adige, bordering on Austria, with German as a second language. Below the level of regions, 107 provinces are defined in the statistics.[1] Furthermore, Italy is known for its “industrial districts” which often cover a small territory within one or more provinces, with specialized manufacturing or services (**Becattini** *et al.*, 2003; **Bertamino** *et al.*, 2017). These districts are highly innovative and mainly located in the northern part of the country (**Biggiero**, 1998). Using 2011 census data, *Statistics Italy* (*Istat*) distinguished 141 industrial districts and furthermore 611 so-called local labour systems (“sistemi locali del lavoro”, SLL) based on commuting patterns. Insofar as SLLs overlap with industrial districts, the data allows for economic analyses at the district level (e.g., **Paci**; **Usai**, 1999; **Mameli**; **Faggian**; **McCann**, 2008). Industrial districts, however, are not a separate level of administration and hence not included in the national statistics.

Italy is administrated in terms of twenty regions of which five have a special status

The regions have gained importance as innovation-policy units since 2001, when the Italian constitution was changed (*Riforma del Titolo Quinto*). A range of devolution measures gave regional governments greater control over policy areas such as health, education, and economic and industrial development, including innovation policy (**Rolfo**; **Calabrese**, 2006). This devolution led to a sharp reduction of the national budget for the support of industrial and R&D activities, particularly in the South. **Brancati** (2015) estimates that between 2002 and 2013, state aid decreased by 72%; the remaining state interventions privileged Central and Northern Italy, while industrial policies in favor of the Southern regions were virtually abandoned after 2000 (**Prota**; **Viesti**, 2013).

Against this backdrop of devolution, the 2007-2009 economic and financial crisis has severely impacted the Italian industrial system. Compared with the trends calculated for the 1992-2008 period, about 300 bn Euro of gross investment were lost in Italy between 2008 and 2013 (**Cappellin** *et al*., 2014). Southern regions were disproportionally affected: between 2007 and 2012, industrial investment in the South decreased by 47% (**Prota**; **Viesti**, 2013). This retreat of national policy has only partly been compensated by regional policies, supported to varying degrees by EU Cohesion and Structural funds. In the EU programs during the period 2007-2013, about 21.6 bn Euro of EU funds (*FESR*/*ERDF* and *FSE*/*EFS*) were allocated to regions in Southern Italy for Convergence objectives (Calabria, Campania, Puglia, and Sicilia) and 6.3 bn to regions in Central and Northern Italy for Competitiveness objectives.

Despite the increasing role played by regional governments in innovation policy, it has remained a subject of debate whether the regional level is most appropriate for the design and implementation of such policies. **Nuvolari** & **Vasta** (2015) characterized Italy as a structurally weak national innovation system in comparison to its main competitors. The country has a weak tradition of university-industry cooperation in research and there is a lack of overal coordination in public policy and R&D support services (**Malerba**, 1993). The diverging performance between scientific and technological activities can lead to major difficulties in the technology transfer of scientific results from universities to firms due to a lack of bridging institutions (e.g., **Balconi** *et al*., 2004).

A number of studies in various sectors of the Italian economy (e.g., **Antonioli** *et al*., 2014; **Belussi** *et al.,* 2010; **De-Marchi**; **Grandinetti**, 2017; **Lew** *et al*., 2018) have argued that the international orientation of research collaborations means that Italian regions cannot be considered as innovation system. These innovative regions are better characterized as “glocal” systems. They pair a relatively low connectedness at the local level with strong knowledge-intensive relationships at the international level. On the industrial side, this international orientation carries a threat of de-industrialization of innovative districts and regions because new options can easily be bought and relocated elsewhere by multinational corporations (**Cooke**; **Leydesdorff**, 2006; **Dei-Ottati**, 2003).The gradual emergence of knowledge production as an additional coordination mechanism in an industrial system that is otherwise coordinated in terms of institutions and markets introduces the risk of “footloose-ness” (**Vernon**, 1979). Knowledge-intensive services and high-tech manufacturing tend to uncouple an innovation system from a geographical address and can thus be counter-productive from the perspective of regional innovation policies (**Leydesdorff**; **Fritsch**, 2006).

“Despite the increasing role played by regional governments in innovation policy, it has remained a subject of debate whether the regional level is most appropriate for the design and implementation of such policies”

3. The systems perspective

Whereas biological systems increase uncertainty following the entropy law (**Brooks**; **Wiley**, 1986), technological innovation can extend the number of not-yet realized options and therewith the maximum entropy. For example, the capacity of transport across the Alps could be considered as constrained by the capacity of roads and railways such as at the Brenner Pass. As one invented new channels, however, other options became available, such as for example air transport across the Alps or tunnels underneath, which are not constrained by the conditions on the ground. An *innovation* system would not only evolve as a system —like the weather— but can also be expected to generate new options. New options add to the redundancy which is defined in Shannon’s information theory as the complement of the uncertainty to the maximum entropy.

In the case of interactions among three or more analytically different selection dynamics —market selections, technological opportunities, and strength and weaknesses because of geographical endowments (**Oh**; **Phillips**; **Park**; **Lee**, 2016)— mutual information among them can be positive or negative (**McGill**, 1954; **Yeung**, 2008; cf. **Krippendorff**, 2009). When *positive*, uncertainty is generated; when *negative*, the generation of redundancy —the complement of the information to the maximum entropy— prevails, and uncertainty is reduced. The three selection dynamics in that case interact as selective, but potentially overlapping and therefore redundant perspectives on the information contained in the events.

Using this generation of redundancy as an indicator of synergy, we shall show that the understanding of Italy in terms of regional innovation systems is not optimal when synergy is measured in terms of the interactions among (*i*) the geographical distributions of firms, (*ii*) the economic structure in terms of firm sizes, and (*iii*) the technological knowledge bases of these firms as indicated by the *NACE*-codes (*NACE* is the abbreviation for the *Nomenclature générale des activités économiques dans les Communautés Européennes*, used by the *OECD* and *Eurostat*). **Storper** (1997) has called the quality of the relations among these three dimensions —geography, technology, and organization— “a holy trinity.” This accords with the perspective of a Triple Helix of university-industry-government relations in which the dynamics of knowledge, economics, and control are combined with the objective of generating synergy.

In summary, synergy reduces uncertainty by generating new options. Reduction of uncertainty can be expected to improve the climate for investments (**Freeman**; **Soete**, 1997, pp. 242 ff.); new options provide opportunities for the survival of new activities in the highly competitive markets of emerging technologies (**Bruckner**; **Ebeling**; **Jiménez-Montaño**; **Scharnhorst**, 1996). An innovation system which no longer generates new options may increasingly be locked-in.

From the perspective of a Triple Helix of university-industry-government relations, the dynamics of knowledge, economics, and control are combined with the objective of generating synergy

4. Methods

Mutual information in relations among distributions can be measured using information theory (**Shannon**, 1948). First, uncertainty in the distribution of a random variable x is defined as $H_X=-\sum_X p_X \log_2 p_X$. The values of p_x are the relative frequencies of x: $p_X=f_X / \sum_X f_X$. When base two is used for the logarithm, uncertainty is expressed in bits of information. Secondly, uncertainty in the case of a system with two variables can be formulated analogously as

$$H_{XY} = - \sum_X \sum_Y p_{XY} \log_2 p_{XY} \quad (1)$$

In the case of interaction between the two variables, the uncertainty in the system is reduced by mutual information T_{XY} as follows:

$$T_{XY} = (H_X + H_Y) - H_{XY} \quad (2)$$

One can derive (e.g., **McGill**, 1954, pp. 99 ff.; **Yeung**, 2008, pp. 59 f.) that in the case of three dimensions, mutual information corresponds to:

$$T_{XYZ}= H_X + H_Y + H_Z - H_{XY} - H_{XZ} - H_{YZ} + H_{XYZ} \quad (3)$$

Eq. 3 can yield negative values of T_{XYZ} and can therefore *not* be a Shannon-type information (**Krippendorff**, 2009). Shannon-type information measures variation, but this negative entropy is generated by next-order loops in the communication, for example, when different codes interact as selection mechanisms.

In other words, when three selective perspectives operate one another, uncertainty can be added or reduced —on top of the historical variation— by generating mutual information (with the plus sign) or redundancy (with the minus sign) depending on the configuration. Additional redundancy reduces relative uncertainty by adding options to the system. Increasing the number of options for further development may be more important for the viability of an innovation system than the options realized hitherto (**Fritsch**, 2004; **Petersen**; **Rotolo**; **Leydesdorff**, 2016).

Our measure, in other words, does not measure action (e.g., academic entrepreneurship) as *relations* between input and output, but the investment climate as a structural consequence of *correlations* among distributions of relations. However, the distinction between these structural dynamics in terms of changing selection environments and the historical dynamics of relations is analytical: the historical and the evolutionary dynamics are coupled in the events. Eq. 3 models a trade-off between variation and selection as positive and negative contributions to the prevailing uncertainty. The question of systemness can thus be made empirical and amenable to measurement: when the generation of redundancy prevails over the generation of uncertainty, "innovation systemness" is indicated.

In the case of groups (e.g., subsamples at a lower geographical scale), one can decompose the information as follows: $H= H_0 + \sum_G n_G/N\, H_G$ (**Theil**, 1972, pp. 20 f.). The right-hand term ($\sum_G n_G/N\, H_G$) provides the average uncertainty in the groups and H_0 the additional uncertainty in-between groups. Since T values are decomposable in terms of H values (Eq. 3), one can analogously derive (**Leydesdorff**; **Strand**, 2013, at p. 1895):

$$T=T_0 + \sum_G n_G/N\, T_G \quad (4)$$

In this formula, T_G provides a measure of synergy at the geographical scale G; n_G is the number of firms at this scale, and N is the total number of firms under study. One can also decompose across regions, in terms of firm sizes, or in terms of combinations of these dimensions.

The three dimensions are the (g)eographical, (t)echnological, and (o)rganizational; synergy will be denoted as T_{GTO} and measured in millibits with a minus sign. Because the scales are sample-dependent, we normalize for comparisons across samples as percentages. After normalization, the contributions of regions or groups of regions can be compared. The between-group term T_0 (Eq. 4) provides us with a measure of what the next-order system (e.g., the nation) adds in terms of synergy to the sum of the regional systems.

A routine with further instructions is available at *http://www.leydesdorff.net/software/th4* which generates the synergy values from data which have for this purpose to be organized as comma-separated variables with for each case (that is, firm) a unique identifier, a postal code, a size class, and a *NACE* code. The results are organized into a file which can be read into programs like *SPSS* or *Excel* for further processing. We use *SPSS* v.22 to generate the maps of regions in Italy on the basis of the synergy values expressed as percentages of contributions to the overall synergy of the Italian system.

5. Data and descriptive statistics

Statistics Italy (*Istat*) collects firm census data every ten years. In a previous study focusing on the methodology, we used this census data from 2000 for a comparison with data in the *Orbis/Amadeus* database of *Bureau van Dijk* (**Cucco**; **Leydesdorff**, 2014).[2] In the meantime, complete data sets for the years 2008, 2011, and 2015 have become available online from the so-called *ASIA* (*Archivo statistico delle imprese attive*) database of *Statistics Italy*. This database includes all enterprises that performed productive activities for at least six months during the reference year. However, this data does not cover the sectors agriculture, fisheries, and forestry; public administration and non-profit private organizations are also excluded. The data contain 4,514,022 firms in 2008, 4,450,937 firms in 2011, and 4,338,085 in 2015 [the 2000 industrial census data (4,247,169 firms) was organized a bit differently and therefore we use this latter data only qualitatively for the comparison].

Figure 1. Organization of Italy into Northern, Southern, and Central Italy regions. Northern Italy is indicated in dark green, Central Italy is in very light green, and Southern Italy is in light green.
Source: figure produced by the authors using *SPSS* v. 22.

For an analysis of synergy using the three dimensions of the Triple Helix (TH), we need three key variables:

(1) the administrative location of the firm in the form of its postal address indicating the geographical dimension (government);

(2) the *NACE* code indicating the main technology in the knowledge base of the firm, and

(3) the character of the firm in terms of its size indicated as the numbers of employees.

These three dimensions have been used in a number of previous studies about the TH in various nations (see **Leydesdorff** [2018] for a summary).

Table 1. Regional division of Italy at the NUTS 1 and NUTS 2 levels.

Codes of *Istat*	NUTS1	NUTS2	Name of the region	Macro-regions	North- South
	(a)	(b)	(c)	(d)	(e)
1	North-west Italy (ITC)	ITC1	Piemonte	Northern Italy	Northern Italy
2		ITC2	Valle d'Aosta		
7		ITC3	Liguria		
3		ITC4	Lombardia		
4	North-east Italy (ITH)	ITH1 / ITH2	Trentino-Alto Adige		
5		ITH3	Veneto		
6		ITH4	Friuli Venezia Giulia		
8		ITH5	Emilia Romagna		
9	Central Italy (ITI)	ITI1	Toscana	Central Italy	
10		ITI2	Umbria		Southern Italy
11		ITI3	Marche		
12		ITI4	Lazio		
13	Southern Italy (ITF)	ITF1	Abruzzo	Southern Italy (Mezzo-giorno)	
14		ITF2	Molise		
15		ITF3	Campania		
16		ITF4	Puglia		
17		ITF5	Basilicata		
18		ITF6	Calabria		
19	Insular Italy (ITG)	ITG1	Sicilia		
20		ITG2	Sardegna		

5.1. The geographical distribution of firms in Italy

The administrative division of Italy into Northern, Central, and Southern Italy and twenty regions is visualized in Figure 1 and further specified in Table 1. Among other things, we will test the three conventional partitions of Italy in columns *c*, *d* and *e* of Table 1.

Table 2 provides the numbers of firms in the years under study. In the right-most column we added the 2000 data used by **Cucco** & **Leydesdorff** (2014), but since this data was in some respects different we use the previous study only as a point of reference. (For example, Valle d'Aosta was not counted separately in 2000.) The three data points (2008, 2011, and 2015) are sufficient to distinguish trends in the data (Figure 2).

With the exceptions of Trentino-Alto Adige and Lazio, the numbers of firms have been declining during this past decade. This confirms the impression of stagnation since the crisis of 2007-2009. Italy has only partly recovered from this crisis.

5.2. Small, medium-sized, and large enterprises

In addition to the assignment of *NACE* and postal codes, firms are scaled in terms of the number of their employees. SMEs are commonly defined in terms of this proxy. Financial turn-over is also available in the data as an alternative indicator of economic structure. However, we chose to use the number of employees as one can expect this number to exhibit less volatility than turn-over, which may vary with stock value and economic conjecture more readily than numbers of employees. However, the numbers of employees are sensitive to other activities, such as outsourcing.

The definitions of small and medium-sized businesses, large enterprises, etc., vary among world regions. Most classifications use six or so categories for summary statistics. We use the nine classes provided in Table 3 because this finer-grained scheme produces richer results (**Blau**; **Schoenherr**, 1971; **Pugh**; **Hickson**; **Hinings**, 1969; **Rocha**, 1999).

5.3. *NACE* codes

The third dimension of the data to be used is the attribution of *NACE* codes. The classification of firms in terms of the *Nomenclature générale des activités éco-*

Table 2. *N* of firms in 20 Italian regions.*

Region	2008	2011	2015	(2000)*
Piemonte	344,334	339,261	323,184	335,749
Valle d'Aosta	11,959	11,933	11,257	
Lombardia	822,579	818,998	805,755	818,948
Trentino-Alto Adige	83,121	83,656	84,398	82,843
Veneto	406,800	402,976	391,474	405,952
Friuli-Venezia Giulia	88,683	86,797	82,720	89,303
Liguria	132,288	129,708	122,874	132,408
Emilia-Romagna	389,123	370,778	366,475	387,434
Toscana	338,943	332,563	320,167	337,573
Umbria	70,892	69,411	66,455	70,324
Marche	133,261	131,567	126,213	133,942
Lazio	423,059	428,715	426,322	416,460
Abruzzo	100,120	101,115	97,184	100,822
Molise	21,705	21,445	20,631	21,262
Campania	351,688	340,601	336,819	346,337
Apulia	254,431	254,277	249,196	250,264
Basilicata	36,169	35,234	34,586	35,760
Calabria	114,858	110,391	105,878	112,205
Sicily	278,451	273,155	264,480	273,903
Sardegna	111,558	108,356	102,017	108,984
	4,514,022	4,450,937	4,338,085	4,480,473

* The numbers used in the previous study are provided in the right-most column.

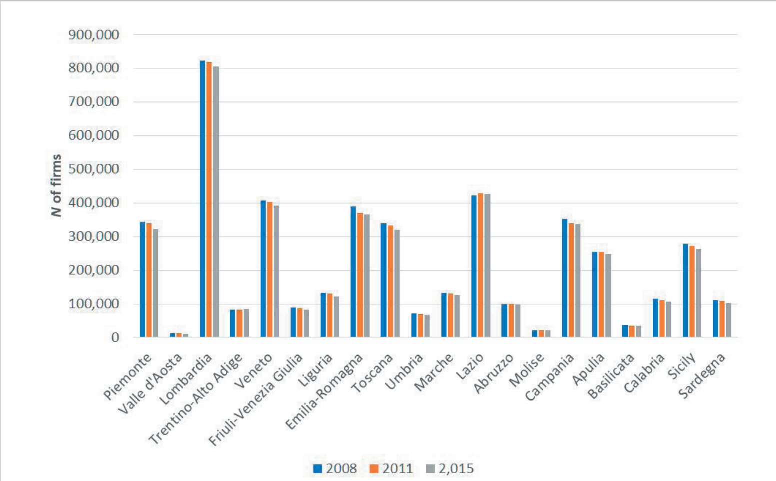

Figure 2. *N* of firms in Italian regions in 2008, 2011, and 2015. Source: *Statistics Italy*.

Table 3. Classification of firms (2015) in terms of the number of employees. Note that micro-enterprises (with fewer than five employees) constitute 91.5% of the firms under study. Source: *Statistics Italy*.

Class	N. employees	Frequency	Percent	Valid %	Cumulative %
1	0 -- 1	3,473,928	80.1	80.1	80.1
2	2 -- 4	493,365	11.4	11.4	91.5
3	5 -- 9	201,497	4.6	4.6	96.1
4	10 -- 19	99,554	2.3	2.3	98.4
5	20 -- 49	45,476	1.0	1.0	99.4
6	50 -- 99	13,275	.3	.3	99.7
7	100 -- 199	6,223	.1	.1	99.9
8	200 -- 499	3,225	.1	.1	100.0
9	500 or more	1,542	.0	.0	100.0
		4,338,085	100.0	100.0	

Table 4. *NACE* classifications (Rev. 2) of high- and medium-tech manufacturing, and knowledge-intensive services.

High-tech manufacturing	**Knowledge-intensive sectors (KIS)**
21 Manufacture of basic pharmaceutical products and pharmaceutical preparations 26 Manufacture of computer, electronic and optical products 30.3 Manufacture of air and spacecraft and related machinery **Medium-high-tech manufacturing** 20 Manufacture of chemicals and chemical products 25.4 Manufacture of weapons and ammunition 27 Manufacture of electrical equipment 28 Manufacture of machinery and equipment n.e.c. 29 Manufacture of motor vehicles, trailers and semi-trailers 30 Manufacture of other transport equipment excluding 30.1 Building of ships and boats, and excluding 30.3 Manufacture of air and spacecraft and related machinery 32.5 Manufacture of medical and dental instruments and supplies	50 Water transport 51 Air transport 58 Publishing activities 59 Motion picture, video and television programme production, sound recording and music publishing activities 60 Programming and broadcasting activities 61 Telecommunications 62 Computer programming, consultancy and related activities 63 Information service activities 64 to 66 Financial and insurance activities 69 Legal and accounting activities 70 Activities of head offices; management consultancy activities 71 Architectural and engineering activities; technical testing and analysis 72 Scientific research and development 73 Advertising and market research 74 Other professional, scientific and technical activities 75 Veterinary activities 78 Employment activities 80 Security and investigation activities 84 Public administration and defence, compulsory social security 85 Education 86 to 88 Human health and social work activities 90 to 93 Arts, entertainment and recreation Of these sectors, 59 to 63, and 72 are considered *high-tech services*.

Sources: *Eurostat/OECD* (2011); cf. **Laafia** (2002, p. 7), and **Leydesdorff** *et al*. (2006, p. 186).

nomiques dans les Communautés Européennes (*NACE*, Rev. 2) is used for indicating the technological dimension.[3] The *NACE* code can be translated into the *International Standard Industrial Classification* (*ISIC*) that is used in the USA (e.g., **Leydesdorff**; **Wagner**; **Porto-Gómez**; **Comins**; **Phillips**, 2019). The disaggregation in terms of medium- and high-tech manufacturing, and knowledge-intensive services, is provided in Table 4.[4]

We will additionally analyze the subsets of high- and medium-tech companies, and (high-tech) knowledge-intensive services, because one can expect different dynamics for these sectors in contributing to synergy in the knowledge base of regions.

6. Results

6.1. Regions

Figure 3 provides a visualization of the percentage contribution of the twenty regions to the national synergy of Italy in 2015. The visualizations for 2008 and 2011 are not essentially different. The rank-order correlations among the regions in these three years are significantly the same (Spearman's ρ > .99; $p < 0.001$).

Figure 3 shows that Tuscany belongs to the northern part of Italy as a knowledge-based economy; the distinction of Central Italy including Tuscany is not supported by this data. Mountainous regions both along the Alps and in the Apennines are weakest in generating synergy. However, one should keep in mind that Italy has a system of excellent highways and trains that cross these regions. Their relative marginality is thus not likely to be due to the mountainous character of these regions, but perhaps more a consequence of their structural positions such as their distance from metropolitan centers, harbors, and airports.

Figure 3. Percentages of contributions of the regions to the national synergy of Italy in 2015.

Figure 6 shows that the triple-helix synergy increased over time in virtually all regions (but not in Sardegna). The strongest regions became even stronger in terms of their contributions to the national synergy. For example, Lombardia increased its leading contribution to the national synergy by another 1.8%. The percentage of synergy generated above the regional level—that is, the complement to 100% of the sum of the regional contributions—declined from 48.9% in 2008 to 44.4% in 2015 (– 4.5%). This reduction of above-regional synergy contribution over time as a percentage is consistent with the progressive withdrawal of innovation policy-making at the national level, and the growing importance of the devolved regions.

In summary: regions have become more important; but only 55% of the synergy is realized at the regional level. The other 45% is realized at the above-regional level (such as NUTS1, across the North/South divide, or in Italy as a whole).

6.2. Northern, Central, and Southern Italy

Using the classification of regions into Northern, Southern, and Central Italy as provided in Figure 1 above, Figure 5 shows the above-regional synergy development using three and two classes of regions, respectively, on the right side, and the values of T_0 on the basis of twenty regions on the left side. As noted, the latter declines from 48.9 to 44.4 %. The above-regional synergy development among the *three* groups of regions (north-south-center) is of the order of 22.5%, but is not consistently increasing as the supplement of the synergy among the twenty regions. Among *two* groups of regions (North-South), however, T_0 is further reduced to 18.2% in 2015.

In other words: if Tuscany is analyzed as belonging to the northern part of the country, this part accounts for 47.0% of the synergy and the southern part for 34.9% with only 18.2% synergy at the national level. Both the northern and southern parts are more synergetic when compared with the division into three parts. Furthermore, values around 20% for the national surplus synergy were also found for other countries in previous studies. Adding Tuscany, which itself contributes only 5.8% to the synergy at the national level, to the northern part (instead of the central one), furthermore,

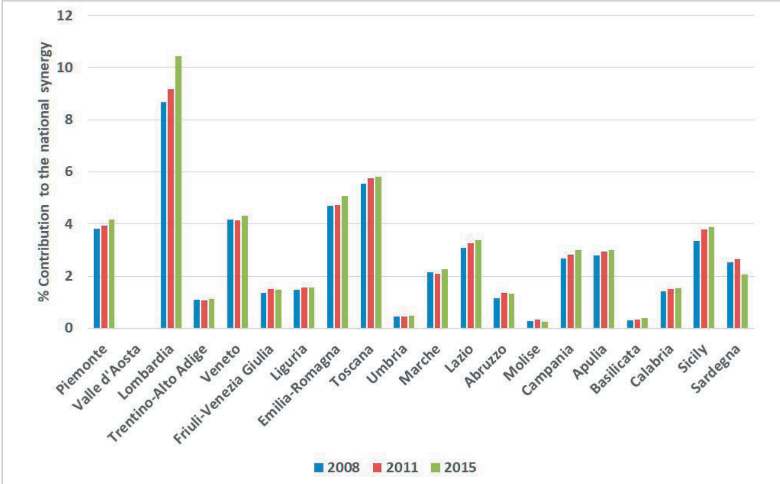

Figure 4. Percentages of contributions of the regions to the national synergy of Italy in 2008, 2011, and 2015.

Table 5. Percentages of contributions of the regions to the national synergy of Italy in 2015.

Region	2008	2011	2015
Piemonte	3.82	3.95	4.17
Valle d'Aosta	0.00	0.00	0.00
Lombardia	8.67	9.18	10.43
Trentino-Alto Adige	1.09	1.08	1.13
Veneto	4.19	4.15	4.31
Friuli-Venezia Giulia	1.37	1.51	1.49
Liguria	1.47	1.56	1.58
Emilia-Romagna	4.71	4.73	5.08
Toscana	5.55	5.75	5.81
Umbria	0.45	0.46	0.48
Marche	2.14	2.10	2.26
Lazio	3.09	3.27	3.38
Abruzzo	1.15	1.37	1.33
Molise	0.27	0.35	0.26
Campania	2.67	2.82	2.99
Apulia	2.79	2.94	3.01
Basilicata	0.32	0.33	0.38
Calabria	1.43	1.50	1.54
Sicily	3.36	3.79	3.89
Sardegna	2.54	2.66	2.07
T_0	48.91	46.48	44.40

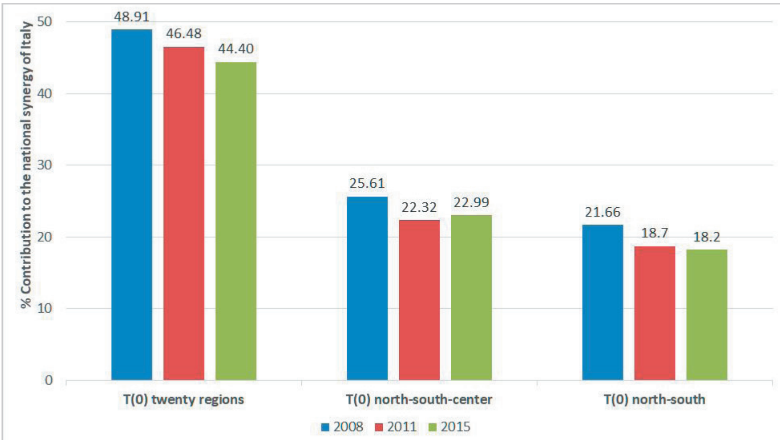

Figure 5. Above-regional synergy for Italy on the basis of 20 NUTS2-regions (left) and three macro-regions (North – South – Center).

increases the contribution of the north by more than 9% (= 46.95 – 37.90; in Table 6). Thus, an additional synergy is indicated by using this model of Italy.

The conclusion is that considering Italy as twenty regions leaves 45% of the synergy in the Italian innovation system unexplained. This is extremely high when compared with other nations. In the USA, we found that the additional synergy at the national (above-state) level is only 2.8%. This is much less than we found in previous studies of national innovation systems: Norway (11.7%), China (18.0%), the Netherlands (27.1%), Sweden (20.4%), and Russia (37.9%).

Italy would score above the Russian Federation when considered in these terms, but for very different reasons (**Leydesdorff**, **Perevodchikov**; **Uvarov**, 2015). The high surplus in Russia is caused by the centralized nature of this system, while in Italy, the high surplus is unexplained because the wrong model is used for the country. When Italy is conceptualized as a country with two or three innovation systems, this description accords with those for other EU nations.

Table 6. Percentage contributions of Northern, Southern, and Central Italy to the national synergy in 2015.

	North-Central-South	North-South
North	37.90	46.95
Center	17.50	
South	21.62	34.85
Sum	77.02	72.80
T_0	22.98	18.20
	100	100

Table 7. Rank-order correlations between the samples of firms classified as high- and medium-high-tech manufacturing (MHTM) and knowledge-intensive services (KIS) over the twenty regions of Italy.

			Full set	MHTM
Spearman's rho	Full set	Correlation Coefficient		
		Sig. (2-tailed)		
		N		
	MHTM	Correlation Coefficient	.955**	
		Sig. (2-tailed)	.000	
		N	20	
	KIS	Correlation Coefficient	.982**	.950**
		Sig. (2-tailed)	.000	.000
		N	20	20

** Correlation is significant at the 0.01 level (2-tailed).

6.3. Sectorial decomposition

Using the *NACE* codes (see Table 4), we can repeat the analysis for subsets of firms which are classified as high- or medium-high-tech, and knowledge-intensive services. Figures 6A and 6B show the distribution of the synergy for these subsets over the twenty regions. Of the approximately 4.3 million firms, 1,294,874 (29.8%) provide knowledge-intensive services, while only 40,083 (0.9%) are classified as MHTM in 2015. However, the differences between the distribution of the set and the subsets are marginal. Table 7 shows the rank-order correlations which are all above .95 (p<.001). In other words: both medium-high-tech and knowledge-intensive services are distributed proportionally over the country in terms of numbers of firms. Table 8 provides a summary of the results, including the values for these subsets as percentages of synergy in the two right-most columns.

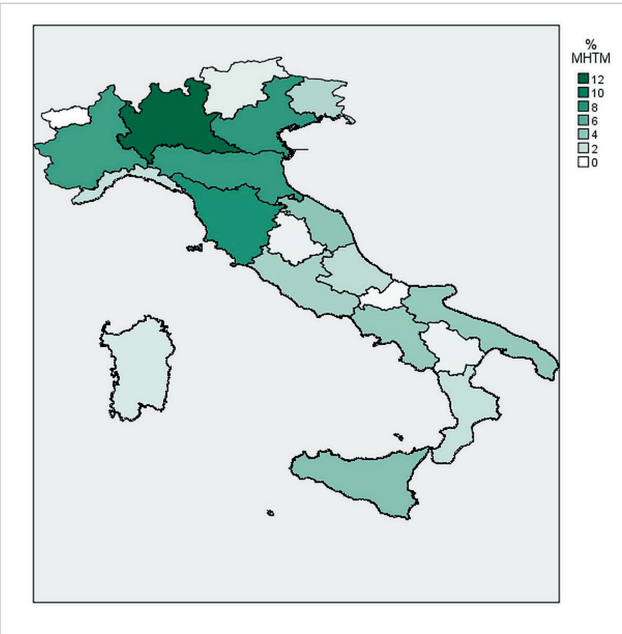

Figure 6A. Regional decomposition of the synergy in the Italian innovation system for medium- and high-tech companies

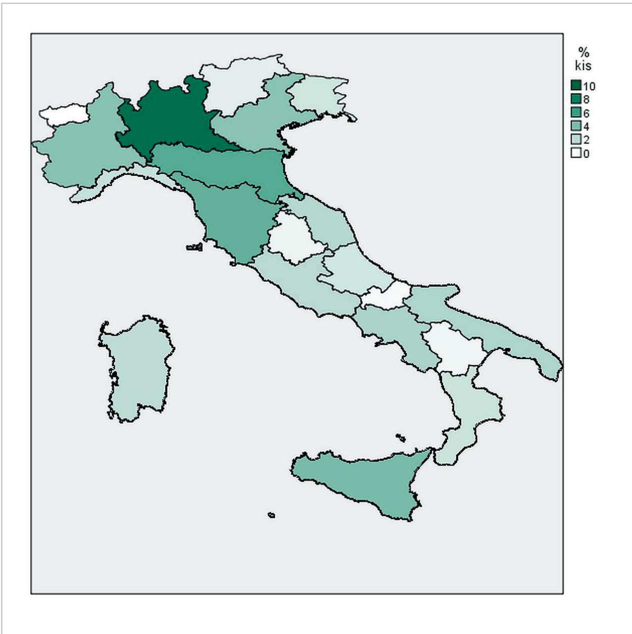

Figure 6B. Regional decomposition of the synergy in the Italian innovation system for knowledge-intensive services.

Table 8. Summary table of percentages of contributions to the synergy in the Italian innovation system (2015)

Region	2015	North_South_Center	North_South	MHTM	KIS
Piemonte	4.17	37.90	46.95	**7.14**	3.58
Valle d'Aosta	0.00			0.00	0.00
Lombardia	10.43			11.68	**9.19**
Trentino-Alto Adige	1.13			0.94	0.80
Veneto	4.31			**7.66**	3.54
Friuli-Venezia Giulia	1.49			2.72	1.38
Liguria	1.58			1.93	1.59
Emilia-Romagna	5.08			**7.40**	5.20
Toscana	5.81	17.50		**8.15**	4.81
Umbria	0.48		34.85	0.67	0.50
Marche	2.26			4.06	2.12
Lazio	3.38			3.07	**2.07**
Abruzzo	1.33	21.62		2.32	1.30
Molise	0.26			0.30	0.21
Campania	2.99			3.70	2.45
Apulia	3.01			3.76	2.36
Basilicata	0.38			0.70	0.42
Calabria	1.54			1.96	1.47
Sicily	3.89			4.44	4.09
Sardegna	2.07			1.34	1.85
Sum	55.60	77.01	71.80	73.94	48.93
T_0	44.40	22.99	18.20	26.06	51.07

We boldfaced in Table 8 some values in the right-most columns for regions with outlier values for MHTM and/or KIS. Piemonte, Veneto, Emilia-Romagna, and Toscana have contributions to the synergy when we focus on MHTM more than two percent higher than without this focus. Lombardia, Marche, and Friuli-Venezia Giulia follow with more than one percent higher values.

Unlike manufacturing, services can be offered nation-wide or even beyond the nation, and thus tend to uncouple from a specific location, leading to a negative effect on the local synergy. In Italy, this is the case mainly for services in Lombardia and Lazio, while these two regions contain the two metropoles of Milano and Rome with airports, etc. Toscana (Florence) and Veneto (Venice) follow with smaller effects.

> Considering Italy as twenty regions leaves 45% of the synergy in the Italian innovation system unexplained, what is extremely high when compared with other nations

In Southern Italy, there are no effects from either MHTM or KIS. A small negative effect of MHTM is indicated for Lazio (3.07 mbits versus 3.08 for the set), probably meaning that some manufacturing may have the administrative offices in Rome without contributing to the knowledge-based synergy in this region (Lazio). Sardegna also has such a negative effect (1.34 versus 2.07; see Table 8) when focusing on MHTM because the medium- and high-tech sectors are marginal in this local economy.

7. Conclusions and discussion

7.1. Summary

Innovation systems are not *a priori* bound by administrative and political borders. In analogy to "national innovation systems" (**Freeman**, 1987; **Lundvall**, 1988; 1992; **Nelson**, 1993), many studies have argued for studying "regional innovation systems" such as Wales or Catalonia (**Braczyk**; **Cooke**; **Heidenreich**, 1998; **Cooke**, 1998; 2002). In our opinion, one should not make the choice between studying regions or nations on *a priori* grounds and across the board. The function of regions in an otherwise relatively homogeneous country (e.g., Denmark) is different from that in a country with a federal structure, such as Belgium.

From this perspective, Italy is an interesting case because there is a traditional divide between the north and the south, but there are also common denominators such as a single language (with small exceptions), national institutions such as a network of state universities, a national research council (*CNR*) with a similar structure in all regions, and a central government without a federal structure. Regions have become more important during the last two decades, because of the devolution policies of the central government and the emphasis on regions in EU policies.

> Italian regions have become more important during the last two decades, because of the devolution policies of the central government and the emphasis on regions in EU policies

One would expect the coherence of an innovation system to be a mixture of both national and regional aspects. The research question was: how much innovation-systemness is generated at the various levels? Is this innovation-systemness distributed across regions or specialized in specific regions? The synergy measure developed in this paper enables us to address these questions empirically.

Italy as a nation is integrated, albeit not only at the level of the twenty regions. Eight regions in Northern Italy (including Tuscany) are well developed as innovation systems. Taken together (Table 5), these eight regions contribute 34.0% to the national synergy. However, as a separate subsystem Northern Italy contributes 47.0% of the synergy (Table 6). This is 13% more than the sum of the individual regions. The regions on the northern borders with different cultural orientations (Alto-Adige and Valle d'Aosta) contribute marginally to the synergy in the northern-Italian system.

If we apply the same reasoning to Southern Italy (the Italian *Mezzogiorno*), twelve regions contribute 21.6% to the national synergy. Considered as a subsystem (Table 6), the South contributes 34.9%; that is, another 13.3% more synergy. On top of these two sub-systems, Italy as a nation contributes 18.2% to the national synergy. Thus, most synergy is found by considering Italy in terms of a northern and southern part, with Tuscany as part of Northern Italy.

The division in terms of North, South, and Central Italy relocates Tuscany into the central part. Using this model, Central Italy improves its 11.9% contribution to the national synergy to 17.5% —that is, +5.6%— while Southern Italy in this configuration improves its contribution from 15.5 to 21.6%, that is 6.1%. The seven remaining regions of Northern Italy in this case generate 28.2% of the synergy as an aggregate, but 37.9% as a single system. The additional synergy is now 9.7% and thus much less than the 13% generated additionally in the configuration of only North and South. Both Northern and Southern Italy (including Central Italy) perform better as innovation systems in terms of synergy generation in a configuration of two sub-systems (North and South). The difference is of the order of 5% synergy.

As one would expect, synergy is enhanced by focusing on high- and medium-tech manufacturing. Rome and Milano function as metropolitan centers of innovation systems, followed by Florence and the Venice region (including the harbour). Unlike Spain, where Barcelona and Madrid function as metropolitan innovation systems without much further integration into the remainder of the country (**Leydesdorff**; **Porto-Gómez**, 2019), the Italian system is well integrated in terms of MHTM and KIS.

7.2. Policy implications

If innovation policy is focused on the regional level, one may miss important opportunities in inter-regional interactions. In other words, the coordination of innovation policies among regions, particularly within each of the two major innovation (sub)systems of Italy, would be desirable. More generally, our results provide further support for the argument that administrative borders which originated for historical or administrative reasons should be examined critically in terms of their functionality for innovation systems, particularly in a knowledge-based economy which is far more networked than a political economy (**Leydesdorff**; **Ivanova**; **Meyer**, 2019).

The knowledge dynamics added to the economic and political dynamics generates a complex system with a volatile dynamics that tends to self-organize its boundaries (**Bathelt**, 2003). A complex system is resilient and thus adapts to signals that do not accord with its internal dynamics. A political administration that is not reflexively aware of and informed about how the relevant innovation systems are shaped, may miss the requisite variety to steer these systems and feel overburdened by the unintended consequences of its own actions (**Ashby**, 1958; **Luhmann**, 1997).

7.3. Limitations

The possibility to search for optima in a phase space of the three (or more) distributions may reveal growth potentials of combinations that have remained hitherto unnoticed (**Rotolo** *et al*., 2017). A limitation of this study, however, remains the quality of the data. The current statistics tend to attribute a single address (for example, headquarters) to firms with multiple locations. In this study, we also used only the first *NACE* code of each firm. Furthermore, the sectors agriculture and fisheries were not included in the *ASIA* data of *Statistics Italy*, while these sectors are critical components of the economy in Southern-Italian regions.

8. Notes

1. These numbers change over time. The current count of provinces is 110.

2. Although the latter sample covered only 402,316 firms as against 4,247,169 firms in the data of *Statistics Italy*, the results at the regional level were virtually similar (Spearman's ρ >.99; p<.001).

3. Firms are classified in the *ASIA* database using *Ateco 2007* codes, the Italian version of *NACE* Rev. 2.

4. A complete index of *NACE* codes can be found, for example, at:
http://www.cso.ie/px/u/NACECoder/Index.asp

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