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Public research in Nanotechnology in Piedmont (Italy)

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Public research in Nanotechnology in Piedmont (Italy)*

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ABSTRACT
Nanotechnologies and nanosciences are a relevant interdisciplinary field in sciences and technologies. They belong to the group of Key Enabling Technologies, and are considered a general purpose and a disruptive technological field. This working paper describes the research activities in nanotechnologies performed inside the regional research system of Piedmont, Italy. After performing a bibliometric search using a tested and reliable methodology, the database of scientific works is analysed. Several features of the nanotech scientific production of the regional research system are analysed: numerical evolution, scientific topics and subject of the works, authors and institutions. The obtained results are commented in the framework of regional systems of innovation. At the end of the analysis, the paper offers comments and draws conclusions.

KEYWORDS
Nanotechnologies, nanosciences, Piedmont, scientific research, regional systems of innovation.

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CONTENTS

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1 INTRODUCTION

Since the end of the last century, nanotechnologies have been among the most relevant technologies for innovation. They belong to the so-called KETs (Key Enabling Technologies), a group of high-knowledge-intensity technologies able to influence the value chain of several producing systems and economic sectors (Schröcker, 2014). Besides, nanotechnologies are also a general purpose and a disruptive technology field (Finardi, 2012). Moreover, scientific research activities in this field have witnessed an impressive growth, as well as an increasing number of published scientific products per unit of time.

Italy has been involved in this stream of scientific production since its beginning. Particularly Piedmont – as the results of the present work will show – has witnessed since the end of the 1990s a strong scientific interest towards this subject. Notwithstanding this interest, Italy's or, more specifically, Piedmont's scientific production in nanotechnology has never been studied in detail. The present work aims at fixing this knowledge gap through the performing of a descriptive analysis of the regional nanotechnology scientific production as a whole, trying to show when, where and how researchers operating in the context of Piedmont have tackled nanotech research topics.

This working paper is an introductive study and it is able to offer only partial and preliminary results, which will help to fill the scarcity of up-to-date information on this subject.

The present work is structured as follows. The next section contains the theoretical framework, discussing in succession the topics of the relevance of nanotechnologies for research and of the regional and sectoral innovation systems, as well as a short review of the literature studying nanotechnologies in Italy and particularly in Piedmont. Section 3 presents methodological issues, while section 4 presents the results of this research. Eventually, section 5 will discuss the results and present the conclusions.

2 THEORETICAL FRAMEWORK

This theoretical framework discusses shortly three topics significant for the present work. The first one is the relevance of nanotechnologies for development. The second one concerns the systems of innovation. The third one mixes the previous two: it regards the importance of nanotechnologies for the Italian systems of innovation. The three topics are significant due to the aim of the present paper, which is to present the features of the nanotech research activities performed in the research system of Piedmont, which is a part of the innovation system of the Region.

Among the works discussing the relevance of nanotechnologies, we must not forget the article of Kupriyanov et al. (2014), which focuses on the importance of nanotechnologies in the development of regional clusters. Their analysis presents the characteristics of different clusters based in different geographic areas (Asia and the U.S.). Also Baglieri et al. (2012) deal with the topic of "nanoclusters" with a specific focus on the cluster of Catania, Sicily, Italy (together with Grenoble, France). The authors assert that "cluster rejuvenation comes from scientific and technological diversity, competition for orchestration, overlap amongst networks and the ability of sleeping anchor tenant organizations to renew actors and technologies" (p. 245).

These two works introduce the second topic of this framework, namely that of the innovation systems. The theory of Systems of innovation originates from the eponymous book (Lundvall, 1992). According to this theory, the innovation process is neither fully automatic (as expressed by the theory of induced innovation) nor fully deliberate (as the theories of R&D management say). Instead, it reflects both creativity and initiative, and production and institutions influence it. A system of innovation acts through this process, exploiting in a systematic way new business opportunities. Knowledge is at the core of innovation systems, which work through the introduction of knowledge into economy and society. Knowledge is the most important resource in contemporary economy and learning is the most important process. Systems of innovation are made by different elements and by their relationships. Such elements interact in the production, diffusion and use of new, and economically useful, knowledge.

Besides innovation systems, also regional systems of innovation have been studied (Cooke et al., 1998). The arising of the concept of "region states" in the early 1990s, together with the crisis of Fordism and the downsizing/resizing of corporate structures, gave rise to the concept of systems of innovation limited to a region rather than to a nation. The growing of new relationships in geographically distinct areas, together with a supporting infrastructure, generated what are called "clusters". Their combination with an innovative, promoting and supporting governance gave rise to a sort of "region-state", a powerful phenomenon able to attract resources from outside its borders. In such a region, firms are set in a frame that is both of collaboration for innovation and of commercial competition.

The efficiency of Italian regional innovation systems is the topic of the work of Barra and Zotti (2018). Their study shows that "it is particularly the contribution of higher education institutions' and private firms' research activities to increase regional innovation efficiency" (p. 454).

Coming to the third and last topic of this theoretical framework, we must first note that the studies concerning the assessment of nanotechnologies in Italy are rather scarce, and thus the evidence on the topic needs to be reinforced. Yet, when Escoffier (2007) reviewed the Italian activities related to nanotechnologies at that time. Italy was "one of the most effective players in the nanotechnology sector" (Escoffier 2007, p. 386). Among the most relevant reported facts, we must note: a non-homogeneous organization of public investments; a much wider number of public bodies involved in the field than industrial ones; the presence of four technological districts having nanotech as a key topic; a vast number of nanotech scientific publications originating in the public sector; a share of patenting almost equally subdivided between public research and industry. In the same years, Arnaldi (2008) did perform a research exploring how the Italian press portrayed the "promises" of NBIC (nano-bio-infotechnologies and cognitive sciences) for the cure of human mind and body. National scientists in natural sciences were the most targeted group of actors in press releases. The tone was overwhelmingly positive. Also in the results of a research reported in Caputo et al. (2009), judgements towards nanotechnologies, deriving from both a sample of informed persons and the public, are substantially positive. More recently, Arnaldi (2014) starts from the stories of three prominent Italian "nanotechnologists" to conclude that they are able to mediate between international expectations on the benefits of nanotech and national activities, with the aim of translating such expectations in terms of local development. The same author, finally, studies Italian regulations in nanotechnologies and explores the opinions of scientists and company managers (Arnaldi 2017).

Calignano and Quarta (2015), instead, study the international network of Italian nanotechnologies examining data on European framework programmes (FP6 and FP7). Findings show that the dynamics of nanotechnologies are located mainly in Northern Italy's "industrial triangle" with other northern regions like Emilia-Romagna and Veneto, as well as Tuscany, while southern Italy runs at a slower pace. Thus, technological opportunities linked to a new emerging sector exacerbate "geographical concentration in core regions" (p. 478).

The sole study on nanotechnologies in Piedmont to date seems being that of Finardi and Vitali (2009). Authors describe research system, technology transfer bodies and initiatives as well as firms involved in nanotechnologies. After performing a SWOT analysis, they conclude that the cluster shows the presence of all the actors of an innovation system.

Once briefly introduced the theoretical basis of this work, it is now time to enter the experimental activity at its core.

3 METHODOLOGY

Aim of the present work is the description of the scientific production in nanotechnologies from the research institutions geographically based in the region of Piedmont, Italy. To this aim, as a first step the methodology entails a data retrieval activity on a commercial database of scientific production. The chosen database has been Elsevier's Scopus®. Scopus has been preferred to other similar databases due to its higher completeness in terms of encompassed journals, books and series.

In order to obtain the database exploited in the present work, the "Advanced" search feature of Scopus has been used. More specifically, the methodology used to search for data has been that described by Arora et al. (2013). This methodology involves the use of a series of queries of meaningful nanotech terms. The terms used assure that the results contains a complete set of nanotech scientific publications and that, in turn, no spurious data are present.

In order to build the database, the queries described in that article on the "Advanced" search mask of Scopus searching on TITLE-KEYWORDS-ABSTRACT. Once obtained the results, the next step has been selecting the names of the research institutions based in Piedmont or that may have branches based in Piedmont (such as for instance the National Research Council of Italy, or industrial companies) in the "Affiliation" search tab. The results deriving from each query have been downloaded and subsequently merged into one list. Once obtained the list duplicates have been removed, and the list has been scanned manually in the "affiliation" column in order to search for spurious scientific products, that is, products where no affiliation relative to Piedmont-based research bodies was present. As above described data mining in fact has been performed including also research bodies (such as the CNR, National Research Council of Italy) having also but not only branches located in Piedmont.

Once cleaned, the list encompassed a total of 288 scientific products on nanotechnologies presenting affiliations of researchers belonging to research institutions (public or private) based in Piedmont. It must be considered that the methodology described by Arora et al. (2013) and adopted in the present work is rather restrictive, as it narrows down the search to only scientific products that are safely nanotech. A comparative search performed using the search key "nano*" on TITLE-KEYWORDS-ABSTRACT and refining as above described rendered an (uncleaned) dataset of over 3,700 scientific publications. It is easy to understand that such a methodology, though probably (not for certain) allows retrieving the full set of nanotech scientific products, includes also a huge quantity of works that have nothing to do with nanotechnologies.

The methodology described by Arora et al. (2013) has then been preferred because the selected scientific publications relate more safely and surely to nanotechnologies. This is in turn at some cost of possibly excluding some scientific works. Thus, though possibly representing only a subset of the total nanotech scientific production of the Region, the dataset exploited in the present work contains only scientific works that relate surely and safely to nanotechnologies.

The dataset obtained using this methodology has been analysed under several points of view. First, years of publication have been aggregated and plotted. Then, an activity has been performed in order to distinguish which research fields are the most studied in the Regional research system. For this purpose, the list of titles present in Scopus has been scanned for Subject categories, assigning to scientific works subject categories relative to each title present in the database and summing the number of scientific products relative to each title according to subject categories. We should consider that most of the scientific products belong to more than one Subject categories, so the sum of values is greater than the number of scientific products. Moreover, 30 titles, for a total amount of 37 scientific products, were not present in the Scopus title list, probably because they have been removed from the list after the articles were published.

Understanding the specific nanotech fields that are involved in the research activities in the Region is obviously of paramount relevance. Therefore, both the titles and the author keywords of the scientific products have been scanned. Once obtained a comprehensive list of keywords and title words, the lists of the most present keywords and (meaningful) title words have been prepared. Non-meaningful words, such as articles and pronouns, have obviously been eliminated from the list.

Another analysis has been performed regarding the authors of the scientific products. A list of names has been prepared out of the "author" field of the scientific products, and the names of the most prolific ones has been associated (via scanning of the websites of the research institutions) with the department they belong to. Out of this activity a list of the departments that are most active in nanotech research has been obtained.

4 Results

The first point that has bee analysed is that relative to the time evolution of Piedmont's nanotech scientific production. Figure 1 and table 1 show the yearly time evolution of the scientific products in the database. The graph shows a growing trend from 1996 onwards, with a slight change of pace around 2006. A linear regression trend line calculated for the trend has angular coefficient 1.26 (intercept = 0) and $R^2 = 0.78$. We should remember that we have to consider the value for 2017 as provisional, as data retrieval has been performed at the end of the same year. Anyway, the growth has been steady notwithstanding unavoidable irregularities.

The analysis of research fields performed using Scopus subject areas has rendered the results presented in figures 2 and 3. Specifically, figure 2 presents the values relative to six most populated Subject categories, while figure 3 presents a split up of the "Other fields" value in five least populated subject categories. Other even less populated categories are not presented for sake of conciseness. It is easily seen that the most populated categories are "Materials Science" (109 scientific products), "Chemistry" (100) and "Physics and astronomy" (85). The fourth Subject category in this ranking, "Engineering" (67 scientific products), has little more than half of the products of the first one. These results show a polarization of research towards nanomaterials rather than bio-nanotech, nanoelectronics or nanoproduction. This field seems tackled under both the "physics" and the "chemistry" declinations.

Under this point of view, a further deepening comes from the analysis of title words and author keywords. The ranking of occurrences of the two sets of data are presented in table 2 (title words) and table 3 (author keywords). Most of the (relevant) title words can be related to nanomaterials: surface, film, nanoparticles. The most represented title word in the list is self-assembled/self-assembly/self-assembling (for a total number of 51 – 20 plus 20 plus 11 – title words). We have to read this value together with the value for "self-assembly/self-assembling" in author keywords (18 plus 5 occurrences) which is at the top of the list. Thus, from this analysis the research topic of self-assembling nanomaterials looks the most frequently studied in the Region.

A relevant information on the Regional research system is relative to the geography of research, that is, the definition of the places where research is performed. For this purpose, an analysis of the authorship has been performed. This method has allowed retrieving the department to which the authors belong, obtaining a more fine-grained analysis with respect to the affiliation field, which often reports only the main institution. Table 4 reports the most active departments of the different institutions. In particular, in INRIM (Istituto Nazionale di Ricerca Metrologica, National Institute of Metrology Research) Department of "Nanoscienze e Nanomateriali" (Nanosciences and nanomaterials) five authors have published more than 10 scientific products. In UniUPO (Università del Piemonte Orientale, Western Piedmont University), four authors have published more than 10 scientific products. Other prolific authors are also present in PoliTO (Politecnico di Torino, Polytechnic of Turin) and UniTO (Università di Torino, University of Turin).

5 CONCLUSIONS

The experimental results deriving from the dataset of scientific publications exploited in this work show a rather multifaceted research environment. It must be considered, prior to comment the results, that the analysed environment is relatively small. Consequently, it is relatively normal that the number of publications present in the database is not extremely high.

Results on the origin of the most prolific authors show that nanotech research activities are distributed over the entire regional research system. There are obvious differences in terms of quantity, but all the research bodies that are involved in research in fields that are relevant to nanotechnologies are present in the list.

Under this point of view, it is also important to note the steady growth in the number of publications across time. If we read these two facts in conjunction, they show that the Regional Research System is strongly involved in nanotech research.

A relevant point to discuss is that of research topics. The relevance of "self-assembling" nanomaterials in regional research has been presented in the "Results section". We could possibly relate to this topic the result for "block copolymers". Other topics that have been widely studied are those relative to nanoparticles (and probably to quantum dots, as title words count seems to suggest), films and graphene, and magnetic materials.

More in general, what we must point out is the disequilibrium of subject categories of research products in favour of Materials science, and then Chemistry and Physics, with respect to other topics such as (nano) Biochemistry/Pharmacology and Engineering. This probably reflects the composition of the research environment, where, besides two generalist universities, a specialized technological university and a specialized research institute are active in the field. However, it is possible that also the composition of the local industrial environment has had some influence on the research topic.

As discussed in the introduction, this paper is able to offer only preliminary and simple results, also due to its structure. Nevertheless, it can offer an insight on the specific topic of nanotech research in the regional research system of Piedmont.

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6 REFERENCES

Arnaldi S. (2014). Exploring imaginative geographies of nanotechnologies in news media images of Italian nanoscientists. *Technology in Society*, 37, 49–58.

Arnaldi S. (2008). Converging technologies in the Italian daily press 2002–2006: preliminary results of an ongoing research project. *Innovation: The European Journal of Social Science Research*, *21*(1), 87–94.

Arnaldi S. (2017). Changing Me Softly: Making Sense of Soft Regulation and Compliance in the Italian Nanotechnology Sector. *Nanoethics*, *11*(1), 3–16.

Arora S. K., Porter A. L., Youtie J. & Shapira Ph. (2013). Capturing new developments in an emerging technology: an updated search strategy for identifying nanotechnology research outputs. *Scientometrics*, *95*(1), 35–370.

Baglieri D., Cinici M. C. & Mangematin V. (2012). Rejuvenating clusters with 'sleeping anchors': The case of nanoclusters. *Technovation*, *32*(3-4), 245-256.

Barra C. & Zotti R. (2018). The contribution of university, private and public sector resources to Italian regional innovation system (in)efficiency. *The Journal of Technology Transfer*, *43*(2), 432–457.

Calignano, G. & Quarta, C. A. (2015). The persistence of regional disparities in Italy through the lens of the European Union nanotechnology network. *Regional Studies, Regional Science, 2*(1), 470–479.

Cooke, Ph., Heideinrich, M. & Braczyk, H.-J. (1998). *Regional Innovation Systems. The role of governance in a globalized world*, London and Bristol (PE): UCL Press.

Caputo, G., Cortese, C. G., Emanuel, F., Finardi, U., Ghislieri, C., & Coluccia, S. (2009). *Nanotecnologie: cosa sono e come ce le immaginiamo (Nanotechnologies: what they are and how we do imagine them)*. Boves: Araba Fenice. ISBN 978-88-9585-353-6

Escoffier, L. (2007). A Brief Review of Nanotechnology Related Activities in Italy. *Nanotechnology Law & Business*, *4*(3), 385–392.

Finardi, U., & Vitali G. (2009). Il cluster delle nanotecnologie in Piemonte ("Nanotechnology cluster in Piedmont). *CNR-CERIS Working Paper Series*, 10/2009.

Lundvall, B.-A. (Ed.) (1992). *National Systems of Innovation – Towards a Theory of Innovation and Interactive Learning*, London: Pinter Publishers.

Kupriyanov, S. V., Avilova Z. N., Kachyrova E. V., Minaeva L. A., & Arkatov, A. Y. (2014). Nanotechnology as a factor in the development of regional clusters. *Journal of Applied Engineering Science*, *12*(4), art. 303, 285–290.

Schröcker, D. (2014). Key Enabling Technologies for European Growth. http://ncp.pu.if.ua/material/priodir/docs/3.pdf (visited on April 2018).

TABLES AND FIGURES

Table 1. Scientific products per year

Year	Scientific Products
1996	0
1997	2
1998	0
1999	3
2000	2
2001	4
2002	2
2003	3
2004	6
2005	4
2006	6
2007	13
2008	18
2009	17
2010	10
2011	21
2012	29
2013	26
2014	33
2015	35
2016	26
2017	26
TOTAL	286

Source: elaboration on Scopus data.

Table 2. Title words count

Title words	Word count
quantum	22
surface	21
films	20
nanoparticles	20
self-assembled	20
self-assembly	20
magnetic	16
molecular	16
synthesis	15
carbon	14
nanotubes	14
thin	13
characterization	12
thermal	12
arrays	11
self-assembling	11
block	10
copolymers	10
dot	10
materials	10
silica	10
mesoporous	9
monolayers	9
nanospheres	9
silicon	9
drug	8
semiconductor	8
delivery	7
imaging	7
Modeling	7
TiO2	7
circuits	6
graphene	6
MRI	6
oxide	6
polymer	6
polystyrene	6
PS-b-PMMA	6
bioactive	5
copolymer	5
core-shell	5
fluorescent	5
Luminescent	5
membranes	5
metal	5
multifunctional	5
spectroscopy	5
supramolecular	5

Source: elaboration on Scopus data.

Table 3. Author keyword count

Author Keywords	Keyword count
self-assembly	18
Block copolymers	9
Carbon nanotubes	8
Graphene	6
Nanoparticles	6
rapid thermal processing	5
Self-assembling	5
Cytotoxicity	4
Drug delivery	4
Functionalization	4
MRI contrast agents	4
PS-b-PMMA	4
Quantum dot	4
q. dot cellular automata	4
Quantum dots	4
X-ray diffraction	4
Block copolymer	3
Dye-sensitized Solar Cell	3
Ferrocenes	3
Luminescence	3
Modeling	3
Nanocomposites	3
nanoMagnet logic	3
Peptides	3
ROS	3
Self-assembled monolayer	3
silicon	3

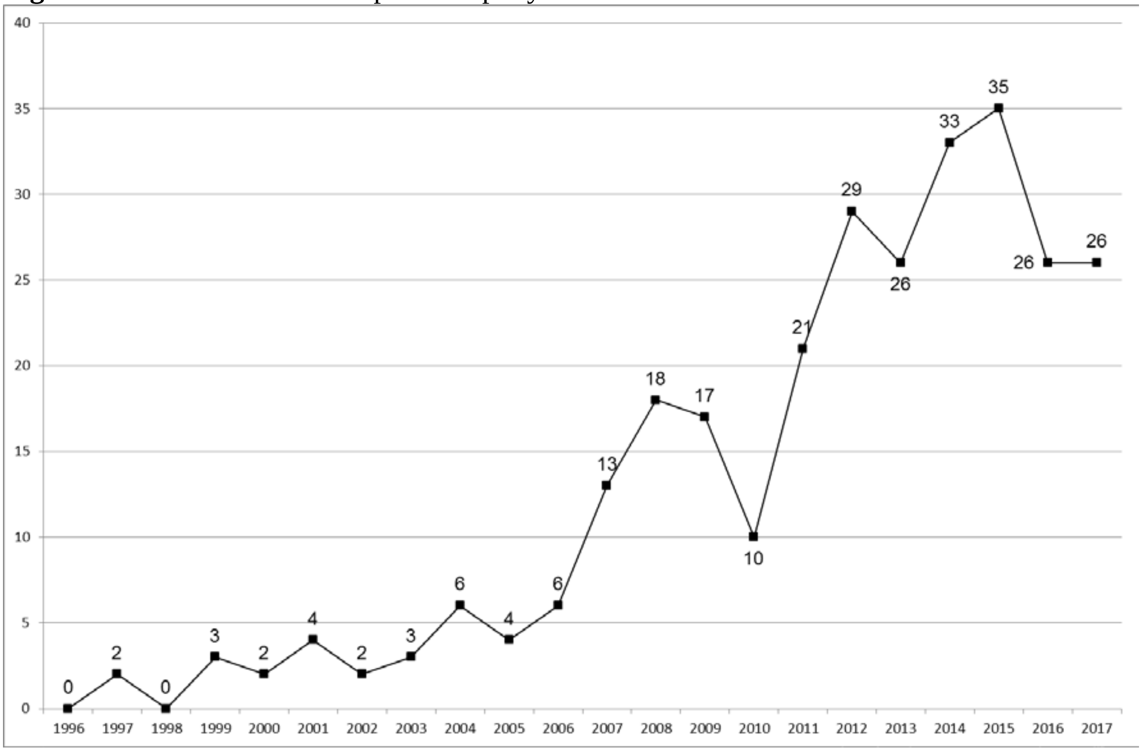
Source: elaboration on Scopus data.

Table 4. Departments most involved in nanotech research

INRIM	NANOSCIENZE E MATERIALI
PoliTO	DET
PoliTO	DISAT
UniTO	Dipartimento di Biotecnologie Molecolari e Scienze della Salute
UniTO	Dipartimento di Chimica
UniTO	Dipartimento di Scienza e Tecnologia del Farmaco
UniUPO	DISIT

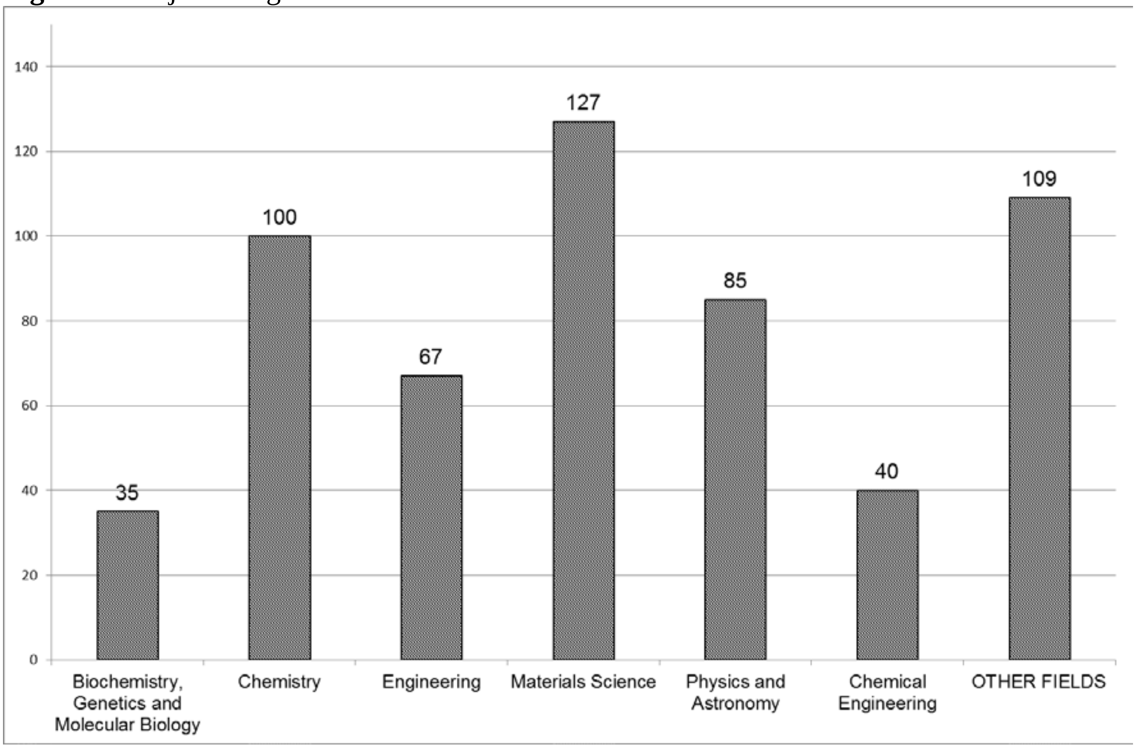
Source: elaboration on Scopus data.

Figure 1. Number of scientific products per year



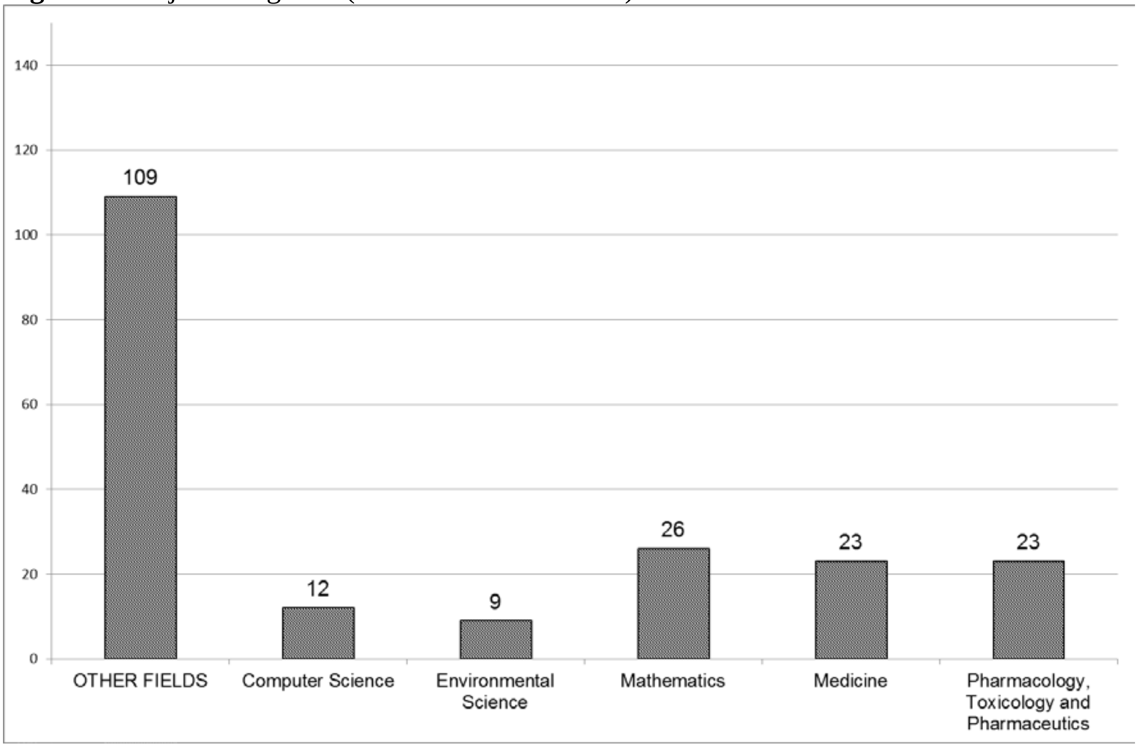
Source: elaboration on Scopus data.

Figure 2. Subject categories



Source: elaboration on Scopus data.

Figure 3. Subject categories (detail of "Other fields")



Source: elaboration on Scopus data.