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Exploring the Intellectual Capital of a High Tech Industry: A Case Study of the Scientific Outputs of Defence Firms

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Abstract:

Purpose: *This paper explores the intellectual capital of the Greek defence industry by performing bibliometric analysis on the (co)authored scientific publications of defence firms. In the context of knowledge economy, scientific outputs are important indicators of the respective intellectual capital, a source of probable future economic benefits that can be retained and managed by firms.*
Design/methodology/approach: *In order to identify the Greek defence firms three data sources were employed: the Registry of Manufacturers of Defence Material, the Greek Defence Material Association (SEKPY) and the Hellenic Association of Space Industry (H-ASI). The total number of firms amounts to 169. Out of this population, 42 firms were identified within bibliometric databases such as Scopus and Web of Science (WoS). Such firms, during the period of 1987 to 2021, have (co)authored 767 scientific publications with 848 different institutional affiliations and fall under 24 different subject areas.*
Findings: *Findings indicate that the number of scientific publications shows fluctuant upward trends over time. In terms of industrial classification, the NACE codes of these over performing firms overlap the respective bibliometric Subject Area Classifications, indicating a coordination between scientific and industrial priorities. At cross-country level, results suggest that affiliated institutional sectors such as the Business Sector and Higher Education Sector contributed equally in terms of scientific output, indicating a strong industry-academia collaboration. Network analysis points out to specific collaboration patterns with the National Technical University of Athens (NTUA), National and Kapodistrian University of Athens (NKUA) and the National Centre of Scientific Research "Demokritos" (NCSR Demokritos) constituting the top collaborators of the Greek defence firms.*
Originality/value: *This study by identifying, imprinting and analyzing metadata emanating from scientific outputs intertwined with a high tech industrial sector enables the debate on knowledge-incentive activities for economic and industrial growth. In view of this, scientific performance, subject areas and network of collaboration are viewed as integral features for monitoring firms' structural and relational capital.*

Keywords: *Intellectual capital, scientometrics, industrial policy, defence, Greece.*

JEL codes: *O25, O32, O34.*
Paper Type: *A research study.*

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1. Introduction

Given that defence is a high-tech industrial class, the issue of identifying the science output formulating and composing this sector is crucial. This has been the case also in other industrial fields that are science and tech-enabled, e.g., pharmaceutical industry (Sachini *et al*., 2021; Yegros-Yegros and van Leeuwen, 2019). Thus, examining the scientific performance of such a sector stands as a legitimate avenue in the aim of identifying the scientific foundation of this industrial class.

Another important frame to examine the scientific activities of defence firms concerns the importance of knowledge-intensive activities as an enabler of economic growth (Moretti *et al*., 2019; Karampekios, 2018; Mowery, 2010). Building on the widely accepted findings that human capital and research activities - two essential elements of knowledge intensive activities - are the leading factors in raising productivity because they facilitate knowledge spillovers and the adaptation of new technologies to economic growth (Carlsson *et al*., 2009), defence firms are viewed as a motor towards this. This line of argumentation is based not only on empirical, country-level findings (Yuan *et al*., 2016), that identify the contribution defence firms on the overall economic growth pattern. It is also squarely placed within the leading theoretical constructs that seek to recognize the elements of the 'knowledge economy' and steer its governance towards increasing levels of optimization, namely the Innovation Systems theoretical approach.

Herein, defence is recognized as a crucial sector (Belin and Guille, 2019). It is within this line of tradition and due to the abundance of econometric data and analyses that the hotly debated issue of positive/negative effects defence spending has on the commercial research, innovation and knowledge-intensive activities can be placed. Understanding the knowledge capital of defence firms is, also, placed within the discussion on (reformulating) industrial policies. Again, a means to achieve economic growth through industrial competitiveness that is based on knowledge intensity and the evolving digital innovation and production patterns. In this context, policy makers in advanced economies have realized the significance of the defence sector in terms of turnover, exports, employment as well as an enabler of digitization, automation and sector cross-disciplinarity. In the case of the European Union, this has dripped down to a number of concrete policy measures that seek to boost the defence technological and industrial capabilities, for example by embedding supply chains, integrating defence into regional innovation strategies, fostering new skills and dexterities, in addition to defence R&D and industrial funding (Fiott, 2019).

Similarly, the US, despite its nominalist rejection of an ''industrial policy'', has been practising state-led optimization industrial initiatives for long (Wade, 2017). The point here is that defence industrial policy in the 21st century is firmly placed within a technological intensity rationale, a key aspect of which is the so-called fourth industrial revolution, that seeks to capitalize on science and technology, thus putting a direct link on outputs coming out from these realms.

1.1 Research Rational, Research Aim and Research Questions

This study building upon recent research (Sachini *et al*., 2020a) seeks to further explore the intellectual capital of the Greek defence firms (hereafter abbreviated as GDF). Herein the term 'intellectual capital' should be taken to mean the scientific publications in peer reviewed journals that have been (co)authored by researchers employed by the Greek defence firms. By the term 'explore', it is meant to inquire and provide a range of relevant metrics that can enhance our understanding of the sector's scientific, technological and industrial performance by means of highlighting the over-performing firms, their industrial classifications as well as the international collaboration network involved in the science output production.

2. Literature Review

Standing on the bibliography on intangible assets as a firm's source of competitive advantage (Nelson and Winter, 1982), scientific publications are considered to be an integral part of the structural capital – a sub-theme of the intellectual capital typology – to be appreciated as a form of codified and cumulative asset (Andrews and De Serres, 2012; Thum-Thysen *et al*., 2017). More on this, focusing on those non-physical assets that can be a considered to be a source of probable future economic benefits and can be retained and managed by companies (Bontis, 1998; Chen *et al*., 2004), scientific publications are viewed as a special case of R&D activities that constitute transfering mechanisms to circulate knowledge around among both firms and, especially, through their physical embodiment, i.e., the specific employees-acting-as-authors.

Attempting to identify a standard manner upon which the defence-related bibliography views the intangible assets, and more especially scientific publications authored by defence firms the search results were limited.

Excluding recent conducted research (Sachini *et al*., 2020a), most studies did not touch the subject at all (Trajtenberg, 2006) or focus solely on the management of technological insertion; however without addressing specific science-related aspects such as publications (Kerr, Phaal and Probert 2008). Other studies discuss the matter in a largely peripheral manner stating that defence firms 'are more likely to control their intangible assets' (Matthews, 2019), pointing to the classified and limited information realities pertaining defence and, as such, the inability to shed light on the topic. While the card of national security can always be presented with the purpose of putting a stop to such discussion, the fact of the matter is that defence firms by nature of their advanced technological capabilities and high diversification, in terms of human-, structural- and relation-based capitals, in addition to their global character of their operating environment, are long due to adapt to this intangible-based valuation frame of analysis.

Given that R&D activities positively affect the market valuation of firms (Hall, Jaffe and Trajtenberg 2005), this defence-relevant strand of research can delve into the better-researched realms of pharmaceutical and technology-intensive sectors (Mc Namara and Baden-Fuller 2007; Yegros-Yegros and van Leeuwen 2019).

3. Research Design

3.1 Research Methodology

A range of bibliometric data were analyzed in order to perform an analysis of the scientific community (contributors) and outputs (publications). More specifically, on a macro-level, for each firm, the scientific productivity in terms of the number of scientific publications per year was measured. This was conducted in order to identify the top performing firms. On a micro-level, the researchers and their affiliations that compose the firms' intellectual capital were identified. The latter was conducted with the aim of identifying the collaboration patterns intertwined with the production of the scientific output.

On top of that, the standardized classification frame 'NACE Rev. 2 - Statistical classification of economic activities' [2] is followed as a means to obtain a perspective of each firm's subject orientation, the industrial classification of the most productive firms was collected. In view of this, the underlying subject areas across all publications were harvested providing an overview of all the contributing scientific areas in relevance with the priorities of the industries.

With regards to descriptive analysis, as an initial step, the total number of authors as well as the total publications were calculated. For each publication year, a plot depicting the scientific activity of all firms was created. Moreover, the percentage of the relevant subject areas attributed to each publication was computed. In an attempt to highlight firms that stand out in terms of productivity, relevant graphs are presented together with the representation of their industrial classification.

As regards the scientific collaboration, all co-authoring institutional affiliations contributed to the scientific output were identified and further classified into institutional sectors (OECD, 2015). In order to schematically point out the international collaboration network and its subsequent patterns, the methodological framework as discussed in Sachini *et al*. (2020b) in the "Graph analysis" section is followed.

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[2] *https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/KS-RA-07-015*

3.2 The Sample

As a first step, it was necessary to establish which were the domestic defence firms. To do so, we cast a large conceptual net. Specifically, three data sources were employed. The one concerns the Registry of Manufacturers of Defense Material. This registry is preserved, updated and regulated by the Greek Ministry of Defence and concerns those firms that have been accredited by the Ministry as capable of delivering defence and defence-related public work. The two other registries are sectoral. That is, in Greece, two defence industrial associations have been registered.

The one is the Association of Greek Defence Material Association (SEKPY) and the other is the Hellenic Association of Space Industry (H-ASI). SEKPY has a clear-cut defence industrial orientation, whereas H-ASI focuses on space, including its defence and defence-related applications, technologies and products. Members of both were harvested. Given that we collected those firms that have been accredited as defence-relevant by the domestic public authority (Ministry of Defence) as well as that are members of the dedicated industrial associations, the following Table 1 presents the number of those firms. After removing duplicates (firms existing in more than one category) the total number of firms that we focused on amounts to 169.

Table 1. *Distribution of the domestic defence firms across registries*

<table>
<tr><th></th><th>Number</th><th>Total (excluding those overlapping</th></tr>
<tr><td>Registry of Manufacturers of Defense Material</td><td>32</td><td rowspan="3">33</td></tr>
<tr><td>SEKPY</td><td>129</td></tr>
<tr><td>H-ASI</td><td>41</td></tr>
<tr><td>Total</td><td>202</td><td>169</td></tr>
</table>

Source: *Own study.*

To employ bibliometric analysis on the outputs of those firms, it was necessary to obtain the English name of the firms. Of the 169 industries, 137 industries (81%) had had their names provided in the registries with latin characters, including their English commercial name. As regards the remaining 32 firms (19%), a transliteration process into English was performed.

In order to explore the intellectual capital of those Greek defence firms, the relevant knowledge/scientific assets needed to be explored. For the purposes of this research, two main bibliometric databases were complementary utilised, Scopus, Web of Science (WoS). Web of Science and Scopus are the two most extensive databases that provide sufficient stability of coverage (Harzing and Alakangas, 2016). Thus, one can safely assert that these two bibliometric databases are the dominant global players in the field providing a near-total coverage.

3.2.1 Data Scraping

As a first step, using each firm's commercial name as a keyword variable, Scopus database was searched. Specifically, the Scopus section 'advanced search' was probed and queries with specific structure were performed (AFFIL('FIRM NAME') AND AFFILCOUNTRY('GREECE')). Through this iteration, 42 firms were identified as entities that had had scientific publications registered under their commercial name. To verify the outcomes of the research, the Web of Science (WoS) database was also probed. All 169 firms were searched for (queries' structure: AD = ('FIRM NAME') AND CU = ('GREECE')). However, only 32 were identified within WoS. Of those, in 23 cases, the number of publications were identical to those identified in Scopus and in the case of 9, less. As such, only the data retrieved form the Scopus database were considered for analyses purposes.

3.2.2 Data Collection

The identification of the aforementioned 42 firms enabled the research and allowed the locating and downloading of information relevant to their bibliographic profile. Specifically, the following variables related to the bibliometric performance (Waltman and Noyons, 2019) of each firm were the subject of the retrieval process: number of authors, year of firms' publications, the subject areas, as well as the corresponding author institutional affiliations of for each publication. An algorithm (via forming XPath queries) using as input each firm's name and output the aforementioned bibliometric variables was implemented within the Python (3.8.1) environment. Two nested dictionaries were created. The main one used the firm names as 'keys'. The second used the publication year, the authors' names, the authors' publications, the subject areas and the authors' affiliations as 'keys'.

For example, 'Firm A' has in total 20 publications (14 authored by author XX in 2020 and 6 authored by author YY in 2021). Of the 20 publications, 18 fall in the scientific domain of Engineering and Computer Science and 2 of the Engineering and Life Sciences. Then, the dictionary is automatically filled in as follows:
{'Firm A': {2020: (XX, 14), 2021: (YY, 6), Subject Areas: (Engineering, 20), (Computer Science, 18), (Life Sciences, 2), Affiliations: [All affiliations per publication]}}

The dataset regarded the time interval from January 1987 to May 2021 and the download took place on 03/10/2021.

3.3 Research Variables

The research variables include the following:

Year of Publication: The corresponding year of each scientific publication.

Affiliations: The authors' affiliated institution as indicated within each scientific publication.

Subject Areas: The respective field of science (FoS) attributed to each scientific publication[3].

4. Research Results and Discussion

The results section is divided into 2 sub-sections. With respect to the identified firms, the first part (Section 4.1) presents the number of publications over time, the most and least productive companies as well as the subject areas under which these publications can be classified. With the aim of examining the convergence of the aforementioned areas with firms' industrial priorities, the fields of economic activities of such firms were identified. Part 2 (Section 4.2) goes beyond a firm-oriented view focusing on the collaboration patterns rising from the science publications metadata. It presents results pertaining to the affiliated institutional sectors involved in the production of the scientific output. By performing network analysis, the international co-authorship network is imprinted in terms of clusters in which specific collaboration patterns and major institutional sectors are highlighted.

4.1 The Firms: Scientific Performance, Subject Areas and Industrial Activities

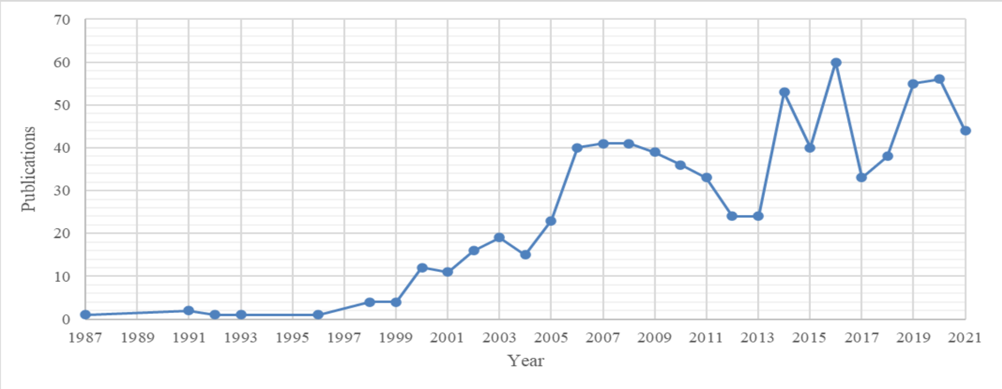
The total number of publications with reference to all the firms (42) identified from the bibliometric database amounts to 767. The corresponding authors of those firms amount to 233. Following Scopus' categorization (see section *'Data Collection'*), these publications pertain to 24 different subject areas.

Figure 1 plots the annual trends of GDF's science outputs. According to the documentation provided, the first article was published in 1987. Since then, a relative slow increase in the following 17 years until 2004 can be observed. After this period and between 2005 and 2008, scientific publications reached their (local) maximum (41 documents in 2007) until gradually decreasing for the next 5 years (24 documents in 2013). From 2014 and on, the number of publications increased substantially, reaching its (global) maximum in 2016 (60 publications). This increase can be potentially attributed to the introduction of defence as a European R&D funding priority (Karampekios *et al.*, 2017; Karampekios, 2018). Among the list of expected deliverables, scientific publications are a preferred outcome of a European-level R&D collaborative arrangement. Analysis of the 'disclaimer' and 'funding acknowledgement' parts' of each publication in future bibliometric

[3]*We follow Scopus All Science Journal Classification (ASJC) model. See:* *https://service.elsevier.com/app/answers/detail/a_id/14882/supporthub/scopus/~/what-are-the-most-frequent-subject-area-categories-and-classifications-used-in/*

analyses can explore this. It is to be noted that in 2021 the steep decrease observed is attributed to the fact that the bibliometric dataset downloaded had not (at the time of the download) incorporated the 2021 publications.

***Figure 1**. The annual trends of GDF's scientific outputs regarding the period 1987-2021.*



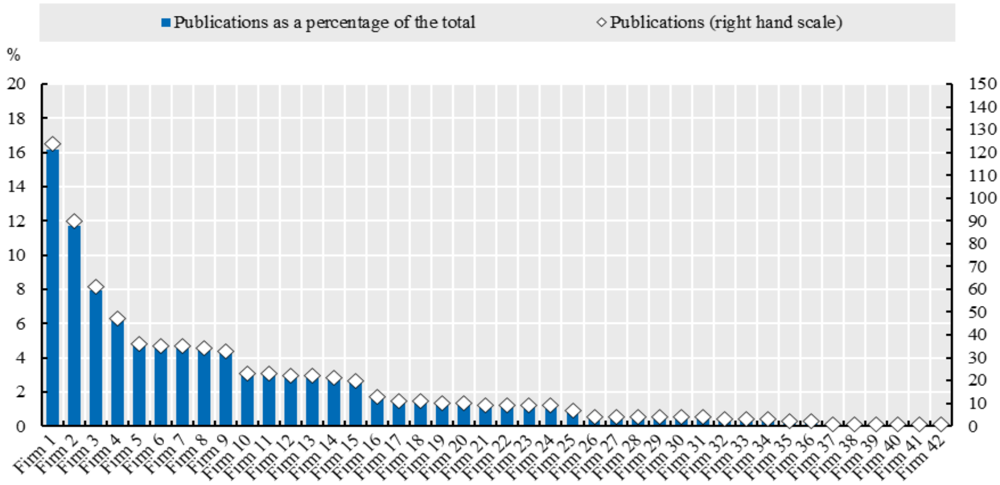
***Source:** Own study.*

In Figure 2, the most and least productive firms in terms of number of publications are presented. Firms are positioned in the x-axis in relation with their number of publications in descending order. Firm #1 clearly outperforms the rest of the firms with 124 affiliated publications, accounting for the 16.2% of the total number of publications. This firm is classified in terms of economic activities as "Manufacture of air and spacecraft and related machinery" (NACE Rev2 code - 3030). This firm is the Hellenic Aerospace Industry (see Appendix, "Defence Firms" excel sheet).

The Hellenic Aerospace Industry is one of the largest industrial enterprises of Greece (Loukis *et al*., 2011). Since 1975 it has been one of the major state-owned defence companies in Greece with 3,000 employees and an established reputation in the international market as a reliable service provider and business partner in the field of combat and civilian aircrafts (Inkster, 2017). Firm 2 has (co)authored in total 90 publications while firms (#3 to #9) have corresponding affiliations in more than 30 scientific publications each. From Firm #16 downwards (until Firm #42), no firm has more than 13 publications in total. One can point to a national system that comprises an outstanding firm in terms of science outputs and a small number of followers that manage to sustain a science production.

Table 2 presents the distribution of the subject areas of these publications. For all 767 publications, a specific scientific Subject Area Classification according to the Scopus taxonomy was attached. 'Engineering' constitutes the scientific subject area under which the greatest number of publications have been categorized with a total of 423 papers, accounting for 55.1% of publications overall fields. 'Computer Science' (317 papers – 41.3%), 'Physics and Astronomy' (138 papers - 18%), 'Materials Science' (128 papers- 16.7%) also make an important contribution in the GDF's knowledge capital. The super-set of the Subject Area Classification class is the generic Subject Area Class. Following Scopus generic Subject Area Class[4] and classify the subject area of a publication accordingly. In total, 90% of the papers fall under 'Physical Sciences' - the most contributing scientific subject area. 'Social Sciences' (5%), 'Health Sciences' (3%) and 'Life Sciences' (2%) complete the scientific map of the GDF's related publications.

Figure 2. *Distribution of firms according to their number of publications regarding the period: 1987-2021.*



Source: *Own study.*

Table 2. *The Subject Areas Classifications of GDF-related publications (%)*

Subject Area	**Publications**	**Percentage**
Engineering	423	55.1
Computer Science	317	41.3
Physics and Astronomy	138	18.0
Materials Science	128	16.7
Mathematics	89	11.6
Earth and Planetary Sciences	47	6.1
Energy	41	5.3
Decision Sciences	36	4.7
Social Sciences	36	4.7
Chemistry	35	4.6
Environmental Science	34	4.4
Chemical Engineering	33	4.3
Medicine	25	3.3

[4]https://service.elsevier.com/app/answers/detail/a_id/14882/supporthub/scopus/~/what-are-the-most-frequent-subject-area-categories-and-classifications-used-in/

Business, Management and Accounting	17	2.2
Biochemistry, Genetics and Molecular Biology	15	2.0
Health Professions	11	1.4
Agricultural and Biological Sciences	10	1.3
Economics, Econometrics and Finance	5	0.7
Pharmacology, Toxicology and Pharmaceutics	5	0.7
Arts and Humanities	4	0.5
Multidisciplinary	2	0.3
Nursing	2	0.3
Immunology and Microbiology	1	0.1
Neuroscience	1	0.1

Source: *Own study.*

Identifying the specific industrial class under which these firms operate would signal in a direct manner those classes that are highly productive in terms of tangible science outputs, i.e. scientific publications. Hence, the issue of industrial classification of those firms is important. To do so, the standard 4-digit NACE codes are utilised[5]. Figure 3 provides an image of the industrial classification of the top 10 firms. Firm #1 is classified as Manufacture of air and spacecraft and related machinery ('3030'), whereas firms #2 and #3 and #8 as Computer programming activities ('6201'). This indicates that such firms have identical subject orientation, in particular computer science - oriented subjects.

In all, the industrial classification of the top 10 appears to match with most contributing ('Engineering', 'Computer Science', 'Physics and Astronomy', 'Materials Science') 'specific Subject Areas Classifications' of their respective publications, as presented in Table 2. This is an important finding indicating that the scientific classifications are in line with the industrial ones.

4.2 National and International Collaboration Network

4.2.1 Institutional Sector Contribution

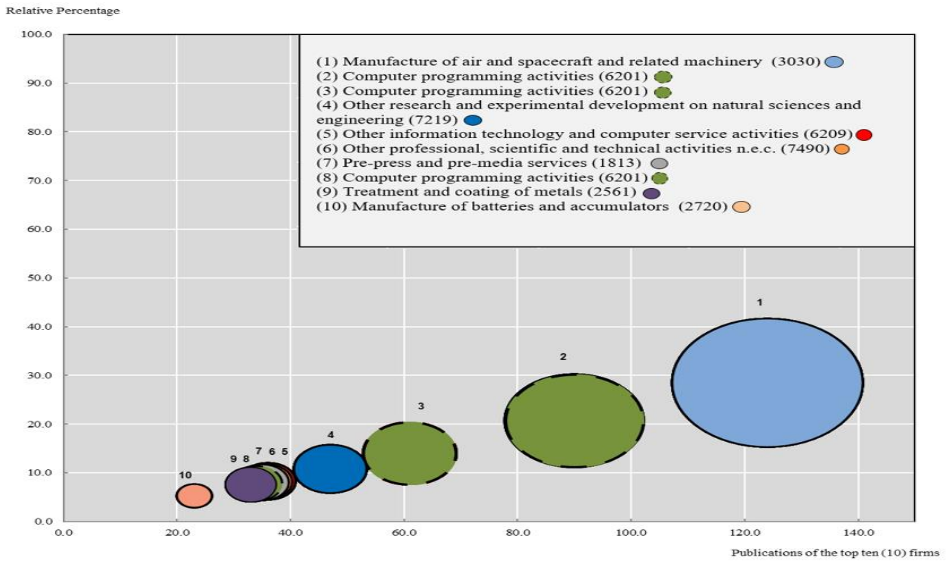
For the purposes of understanding the national and international institutional sectors' contribution to the scientific output, the affiliated institutions were distributed according to the accepted institutional sectors HES, GOV, BES, PNP[6] and its subclasses following OECD's Frascati taxonomy (OECD, 2015). Observing Figure 4 it is evident that the Business Sector (BES) and the Higher Education sector (HES) contribute almost equally in terms of the number of science outputs produced. In total they account for the 80% of the authored scientific publications (41% and 39%

[5]*The NACE Rev. 2 - Statistical classification of economic activities is followed. See https://ec.europa.eu/eurostat/web/products-manuals-and-guidelines/-/KS-RA-07-015 .*

[6]*Higher Education Sector (HES), Government Sector (GOV), Business Sector (BES), Private Non Profit Sector (PNP).*

respectively). Enterprises contribute the most scientific publications of the BES sector (40.8%) while Universities authored the majority of those as regards the HES sector (37.5%). The Private non-Profit sector (PNP) is associated with the smallest number of publications, and, as regards the GOV sector, the majority of the publications has been authored by research institutions (9.94%).

Figure 3. *Representation of the industrial classification of the top 10 firms with respect to their scientific performance.*



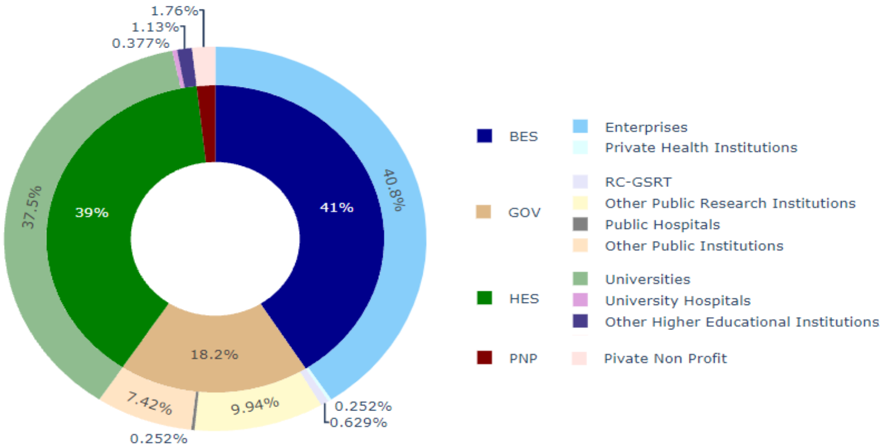
Source: *Own study.*

The above indicate a strong industry-academia collaboration in producing science output. Collaboration between such in stitutional sectors helps to ensure industrial relevance in academic research and supports improvement and innovation in industry. That is, university–industry technology transfer (UITT) especially in such high-tech industries is a vital component for industrial research and innovation as well as economic growth (Arshed *et al*., 2021; Wohlin *et al*., 2011; Lee, 1996).

4.2.2 Institutional Sector Scientific Network

All 767-related publications have been (co)authored and are associated with 848 unique institutional affiliations (see Appendix, 'Affiliations' excel sheet). The network (Figure 5) presents in terms of clusters the underlying institutional affiliations that contributed to the authoring of the GDF scientific publications. The size of the nodes and affiliations' font represents the weights (impact) of the nodes. The larger the node and the font are, the larger the weight is. The distance between two nodes reflects the strength of the relation between two nodes. A shorter distance generally reveals a stronger relation. The edge (line) between two affiliations represents that such institutional affiliations have appeared together. The thicker the line is, the greater their co-occurrence.

Figure 4. *Scientific output contribution of national and international institutional affiliations classified by sector and subsector*



Source: *Own study.*

With the aim of imprinting a *connected* ecosystem of scientific knowledge both at a national and international level, GDF that have not authored any scientific publications with each other were excluded from the network. That is, the graph was constructed taking into account solely Greek defence firms that have collaborated - in terms of co-authoring scientific publications - at least once (1) with another Greek defence firm. As such, 141 institutional affiliations met the threshold accounting for the 16% of the total. The analysis generated six different clusters (shown in red, blue, yellow, green, light blue and purple). Every cluster depicts the scientific connections between the collaboration countries (Figure 5).

Observing the affiliations' positioning in the network and being guided as well by the node it is evident that 'National Technical University of Athens (Ntua)' collaborated the most with the GDF with respect to the other institutional sectors. In fact, Table 3 shows that it has the highest frequency of 25 meaning that authors affiliated with the National Technical University of Athens have co-authored at least one scientific publication with 25 different Greek defence firms (60% of the total GDF) .

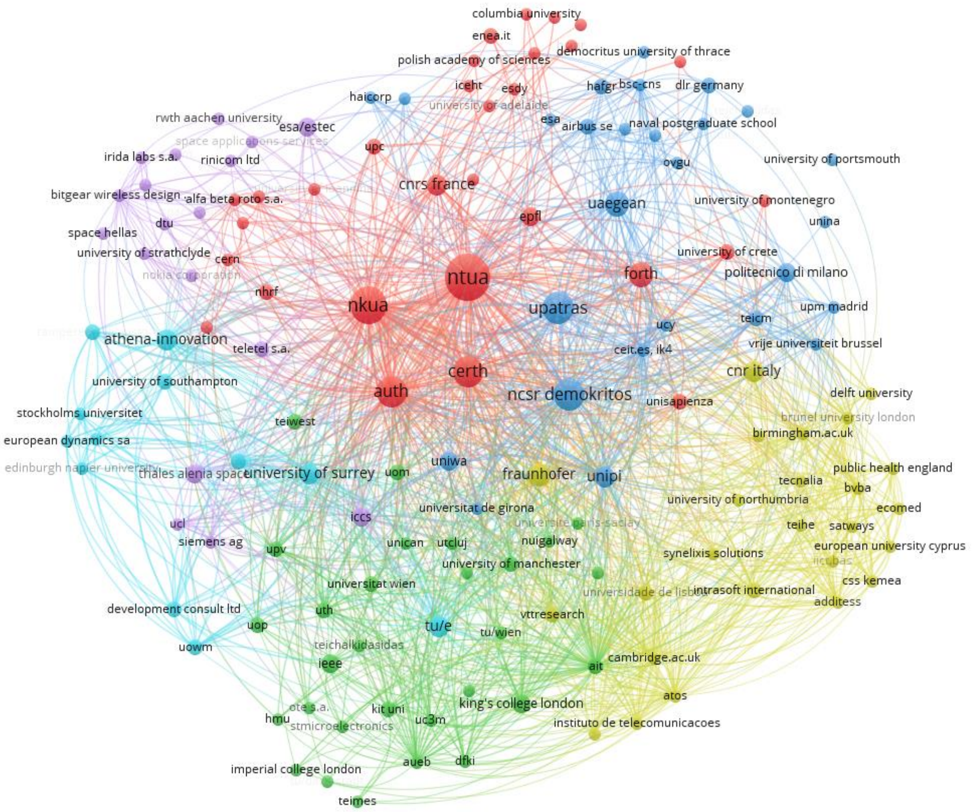
In total, the National Technical University of Athens has co-authored 351 scientific publications (total link strength) with the aforementioned firms, indicating that it has the most connections among all the affiliations in the international scientific collaboration network. It should be noted that 'Fraunhofer' and 'Unipi' although being at the bottom of the top-10 list in terms of frequency, posses a total link strength of 188 and 182. This indicates that although both collaborated with a little number of firms (6 and 5 firms respectively), their degree of collaboration is strong (188 and 182 publications respectively).

Table 3. *The top 10 institutional affiliations of the GDF-related publications*

Rank	**Affiliations**	**Frequency**	**Total Link Strength**
1	Ntua	25	351
2	Nkua	16	296
3	Ncsr Demokritos	12	209
4	Upatras	12	182
5	Auth	11	187
6	Certh	11	167
7	Forth	7	131
8	Uaegean	7	125
9	Fraunhofer	6	188
10	Unipi	5	182

Note: *Frequency refers to the number of GDF with at least one co-authored publication with the corresponding affiliation. Total Link Strength refers to the total number of co-authored publications of the corresponding affiliation.*
Source: *Own study.*

Figure 5. *The international collaboration network.*



Source: *Own study.*

5. Conclusions

Bibliometric analysis concerning defence industries is a little touched field (Burnett *et al*., 2018; Fraunhofer INT, 2020; Sachini *et al*., 2020a). As such, the issue of addressing the intellectual capital of those firms as well as the sector as a whole can certainly attract more attention. All the more given the knowledge-intensity of the sector. While the paper refrains from offering company-centered valuation approximations of these science outputs, shedding light on the bibliometric methods to explore these outputs contributes towards a variety of analyses. In every, case such analyses can be extended on similar national and/or supranational contexts.

Focusing on the Greek defence industrial sector, a range of relevant bibliometric indicators were utilised. Cross-temporal analysis indicates that the number of publications produced by GDF although with few fluctuations, increases. Furthermore, the subject areas of these publications indicate that most fall under ‘‘Engineering’’. This is followed by ‘‘Computer science’’ and ‘‘Physics and Astronomy’’, yielding to an overall expected finding given the strong engineering background and applied research of this industrial sector. Making use of NACE codes, results suggest that their industrial classifications appear to verify the specific Subject Areas Classifications of their respective publications. This suggests that the scientific classifications are in line with the industrial ones – a fact that can be explained as the sector is mutually technology- and knowledge intensive.

In terms of scientific co-authorships, findings indicate that there is a strong industry-academia collaboration that goes beyond the national level. Such a realisation is crucial given the intrinsic sensitivity of information relevant to the defence sector. In view of the above, specific institutional sectors that contributed to the knowledge capital of GDF have been identified and imprinted as components of a connected collaboration network. Specifically, the National Technical University of Athens (NTUA), National and Kapodistrian University of Athens (NKUA) and the National Centre of Scientific Research "Demokritos" (NCSR Demokritos) constitute the top collaborators of the Greek defence firms. Such collaborators constitute an integral part of firms’ relational capital. As such, policies that promote university–industry technology transfer and science diplomacy should be developed.

In fact, alike realisations have prompted relevant policy considerations by e.g. the European Commission to enhance the sector’s technological and industrial capabilities. This is sought by increasing the R&D performance, integrating defence into regional innovation strategies (RIS3), fostering new skills and dexterities of the both the employees and firms classified as defence. The same holds in the US. It is in this industrially related context that a critical aspect of the tangible knowledge both produced and ‘consumed’ by these firms, i.e., scientific publications, is an untapped intellectual capital.

On a parallel footing, what is interesting concerning the literature on intangible assets being viewed as a source of probable future economic growth, is the difficulty of establishing a standardized, consistent and validated enough method to evaluate their contribution for every industry at large (Stewart, 2010; Bontis, 1998). An aspect of this ambiguity potentially lies in the strain of putting a dollar mark-up in scientific outputs such as scientific publications. This paper, while addressing a sector- and country-specific theme, has, hesitantly, touched upon this difficult subject. Indeed, one can argue that regularly monitoring the publication performance of firms through extensive bibliometric analysis, focusing on impact and collaboration analysis, can yield results contributing to the much sought-after intangible-assets monitoring mechanism that valuation and consultancy companies strive for.

On separate note, technological outputs, such as patents, trademarks, etc., as well as the setting of start-ups affiliated with the mother-companies, would allow researchers to understand the commercialisation process of these science outputs. Correlation of bibliometric performance with other R&D-relevant indicators, such as spending and highly educated personnel as a fraction of total employed, as well as comparison with other science and technology intensive sectors, such as pharmaceuticals, is also an avenue for future exploration.

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