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Assessing the innovation capability of EU companies in developing dual use technologies

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Abstract

This study proposes a framework to identify and analyse the European defence innovation ecosystem and to investigate the relevance of dual use inventions, extending previous empirical approaches. 63,714 defence inventions in the decade 2002-2012 were analysed by taking several dimensions into consideration: time, geography, technology, type of innovator.

The main findings indicate an increasing trend of patented inventions covering a wide range of technological fields not only in the traditional defence areas, but also in Information and Communication Technology (ICT) and in instruments for measurement and control. The innovations seem to be quite concentrated: the twenty largest patent holders (firms and government agencies) account for 40% of total defence inventions. The largest geographical source of innovations is the USA, but South Korea has increased significantly in recent years.

Dual use innovations, i.e. military patents subsequently cited by a civilian invention, are identified using a novel method employing patent citations. The proportion of dual use inventions in the whole dataset is 41%, but the value has been decreasing in recent years and shows heterogeneity across technological sectors and geographical areas (the USA reports the highest share, 63.9%). Analysis of knowledge flows suggests significant heterogeneity in the share of intra-border innovations: the European defence innovations are largely cited by US inventions, especially when considering dual use cases.

Index

List of abbreviations

CERTIDER	Register of the Certified Defence-related Enterprises
EC	European Commission
EFTA	European Free Trade Association
EPC	European Patent Convention
EPO	European Patent Office
EU	European Union
ICT	Information and Communication Technology
IPC	International Patent Classification
IPR	Intellectual Property Right
JPO	Japan Patent Office
JRC	Joint Research Centre of the European Commission, Seville
KET	Key Enabling Technology
KIPO	Korean Intellectual Property Office
NUTS	Nomenclature of territorial units for statistics
OECD	Organization for Economic Co-operation and Development
PO	Patent Office
SIPRI	Stockholm International Peace Research Institute
USPTO	United States Patent and Trademark Office
WIPO	Worldwide International Patent Organization

Executive summary

Aims, objectives, and previous evidence

The aim of this study is twofold. Firstly, it aims to provide a method to empirically identify defence and security innovations and disentangle dual use cases focusing on military inventions that subsequent have a civil application. Secondly, the method has been tested on a large sample of patent data from twelve of the largest patent offices worldwide over the years 2002-12. The data collected has been analysed to develop a set of statistics providing quantitative insights into the EU defence innovation framework.

The proposed identification strategy for generating quantitative evidence on the defence sector is timely in supporting the debate on the level of investment in defence in Europe. The European Commission considers defence and internal security to be an area of great relevance for EU member states where cooperation and commonalities should be fostered. The aggregate EU28 spending on defence and security is estimated to be 227 billion Euros, less than half that of the US but it still represents a non-negligible area of investment with increasing trends (EC, 2017a).

Previous literature focusing on defence innovations and analysing the impact of dual use cases with an empirical and quantitative approach is scarce and mostly based on case studies (Schmid, 2017, Lee and Sohn, 2017). The consensus so far is that the diffusion of military technologies in civilian applications has been limited (Schmid, 2017).

Method

This study extends previous empirical approaches by combining various strategies for the identification of defence innovations. The sources of data selected are patent repositories that, although bearing some well-known limitations, guarantee wide coverage (in time, geography, and technology), and provide structured data that can be searched and processed. The identification of defence innovations is based on three criteria: company names (selected defence firms in the SIPRI database), IPC technical codes from patent documents, and the presence of military keywords in patent text fields. The method for the identification of dual use cases exploits the relationships across patent citation networks to identify civil inventions stemming from defence ones.

Data and findings

The proposed method identified 177,143 patents, corresponding to 63,714 patent families in the years 2002-2012.

The defence innovation database shows an increasing trend towards patenting inventions which cover a wide range of technological fields. The inventions are not only filed for patent protection in traditional defence fields (e.g. weapons and ammunition, transport vehicles) but also in the area of “Electrical Engineering”, which contains ICTs, and of instruments for measurement and control. Moreover, the inventions in these non-traditional fields are particularly increasing compared to weapons and ammunitions.

The largest geographical source of patented defence innovation is the USA, but South Korea has significantly increased its contribution during the time frame of the study thanks to the contribution of private firms, national research centres, and government agencies and ministries. Focusing on narrower geographical regions (NUTS2), the twenty largest areas are all within the USA or Europe and account for about 38% of total innovations. Similarly, the first twenty innovators in terms of defence patent portfolio (either firms or government agencies) account for 40% of total inventions. Defence innovation appears to be rather concentrated.

Dual use inventions are identified whenever a defence innovation finds a subsequent civil application, i.e. a defence patent is cited by at least one non-military invention. The proportion of dual use inventions in the whole dataset is 41%: the value shows heterogeneity across time, technological sectors, and geographical areas. When analysing the trend of dual use patents, the yearly proportion is decreasing. Preliminary tests suggest that the reduction of dual use cases is not induced by the identification method, but the result calls for further study to investigate the citation dynamics and explore whether a forward civilian citation (that qualifies the invention to a dual use one) requires a more time than a defence one.

Concerning the technological aspect, weapons and ammunition related fields are less likely to be present as dual use applications (25.5%) compared to the rest of the technological fields. The data also reveals the presence of significant differences across the countries of origin of the defence innovations: the USA reports the highest share of dual use cases (63.9%) while the other countries range between 46% and no cases.

Finally, the study aims to evaluate the magnitude of the relative share of spillover within and across countries by analysing the patent citation network. The results suggest the presence of a significant heterogeneity in the share of domestic knowledge flows. In particular, the defence innovations generated in the European area are significantly cited by subsequent inventions developed in the USA. The pattern is similar when considering dual and non-dual cases but interestingly the share of cross-border spillovers is higher for dual use than non-dual inventions.

Open issues and future developments

Future research could address the limitations of this work and improve identification of defence innovations and dual use cases by using the proposed method. Semantic analyses on the text fields of the citing patent could be introduced for the purpose of improving accuracy in identifying false positive civilian applications.

The use of additional macro level data on the input factors (e.g. national expense in the defence sector) and on the characteristics of the patent systems (e.g. language and cooperation treaties facilitating citation flows) could be introduced to evaluate the correlations in multivariate analyses. This study also presents preliminary results on the dual use phenomenon when the direction is from civil to defence innovations, which call for further research.

1 Review of the literature

This section reviews the extent of the literature that has empirically studied innovation activities in the defence sector and the phenomenon of dual use.

Because this study aims to set up an analytical framework to identify the most important actors in European defence innovation and to investigate the relevance of dual use inventions, the review of previous studies mostly focusses on relevant literature. The assessment of previous methods and operationalisations of the definition of dual use will improve the design of the methodological approach.

The studies reviewed were identified through an extensive search of the titles and abstracts of published peer-reviewed articles in the electronic reference retrieval services Scopus and Web of Knowledge, using a set of keywords that covers the topics under study. In addition, web searches were relied on to collect reports that support the understanding of the general context of the defence sector. All of the retrieved articles were read and analysed, and those pertinent to the scope of the project were selected, focusing on those studies that provide background to this study in terms of content and methodology.

1.1 Framework: defence and dual use

The European Commission (EC, 2017a and 2017b) considers defence and internal security to be one of the main dimensions through which EU can foster cooperation and commonalities between member states. Although EU28 spending on defence and security is less than half the value of the USA's - which amounts to approximately 600 billion Euros according to the latest data available in the "Reflection Paper on the Future of European Defence" (EC, 2017a) - it represents a non-negligible area of investment in the context of public procurement. In 2016, estimates show a value of 227 billion Euros for the EU, with 20% designated to "Equipment and R&D". The trends in investment are forecast to increase for all main world countries (EC, 2017a).

Despite the notable size of defence and security R&D spending, its indirect contribution to the research and innovation activities of industry has been addressed by a limited number of empirical studies (Schmid, 2017). The existing literature focuses on analysing the defence sector from the perspective of the political framework in which decisions concerning investment and expenditure levels are taken, and its impact on economic growth. Scholars found mixed evidence on the relationship between defence spending and economic growth (Morales-Ramos, 2002; Mowery, 2010).

The relationship with civilian R&D not only shows complex dynamics in terms of economic growth but also when considering innovation activities. Military R&D spending might provide support to research organizations that foster civilian innovations (Mowery, 2010). An increase in the expenditure in defence and security would contribute to promoting demand for new technologies through government procurement. Furthermore, as noted by Klein (2001), to overcome a procurement downturn, defence technology suppliers can temporarily push the allocation of resources towards civilian projects ("technology push-over"). Defence firms exert a "demand pull" that drives R&D investment when contracting with governments (García-Estévez and Trujillo-Baute, 2014). Finally, defence R&D activities can support civilian innovation by simply increasing the overall knowledge and technological base (Mowery, 2010).

The term "dual use" is commonly applied to the relationship between military and civilian innovations. However, it has been used in different circumstances to identify different concepts (Watkins, 1990; Molas-Gallart, 1997): co-development of products, civilian application of a military equipment or diffusion of a military technology (or vice

versa), and trade regulation[1] of sensitive products. Watkins (1990) suggested that for spin-off, transfer, diffusion, or sharing of knowledge or products in each specification, the relevant aspect to consider is the capacity to assimilate technologies from other sectors.

The defence and security industries include complex cutting-end technologies which bring significant changes that can revolutionise the sector and drive the technological edge of civilian applications. Consequently, dual use technologies provide the opportunity to improve understanding of military innovation diffusion mechanisms and of the capability of the EU to develop new technologies. The technological evolution is strictly related to the nature of the defence and security required by society. James and Teichler (2014) analysed several foresight studies and found evidence of a declining role of the defence sector in its traditional meaning. They highlighted an ongoing change in the way security is approached from state-centric risks towards a broader view which encompasses the vulnerability of the society and the industrial system (e.g. failure of critical infrastructure, pandemics, environmental change). The authors argue that in the future the growing importance of dual-use technologies is likely to reduce the role of traditional defence companies as developers and lead-users of advanced technologies.

1.2 Empirical studies

Previous studies attempting to investigate the phenomenon empirically are few and far between and have limitations (Schmid, 2017, Lee and Sohn, 2017). The Literature mostly investigates the presence of technology spillovers and the impact of dual-use R&D on the economy and on the innovation activities through case studies (Alic et al., 1992; Smith, 1994; Maclin et al., 1994; Avadikyan et al., 2005; Bellais and Guichard 2006). The general consensus is that military technologies have limited diffusion in civilian applications, although previous studies have not provided sufficient empirical evidence (Schmid, 2017).

In fact, data analysis has a number of limitations First of all, patents and publications, the main sources for technology level data, are not always disclosed when considering inventions of a sensitive nature or are disclosed at the end of their life cycle. Therefore, only a subsample of the total innovations produced by the defence sector is publicly available for analysis. This issue represents a limitation which is not tackled in this study.

Very few studies employed a quantitative identification strategy to collect data on military and defence innovations. These studies relied on IPC codes to identify defence innovations. Acosta et al. (2011) and Lee and Sohn (2017) limited the military technological domain to IPC classes F41 and F42 which concern weapons and ammunition. Acosta et al. (2017) extended the domain by using other IPC codes relevant to the defence sector. The use of such military-specific IPC codes is particularly robust since it significantly limits the inclusion of false positive results: the sampled inventions associated with the technologies of weapons and ammunition are almost always actual military-specific innovations[2]. The trade-off when defining such a strict perimeter is that it does not cover all the technology fields in which defence companies are active. The identification of military innovations based on IPC codes F41 and F42 only focuses on certain technologies that are central to traditional

[1] Concerning the trade of dual use goods, software, and technology the EU exerts control according to Regulation (EC) No 428/2009, which provides for common rules and a list of reference items belonging to several industries.

[2] However, some technologies which are not developed by defence firms nor have specific military applications are included in classes F41 and F42 (e.g. inventions on airbag charges or toy weapons).

defence companies, weapons and ammunitions, while it neglects fields which are relevant but not associated with those IPC codes (e.g. air or naval vessels, structures or engines, special fabrics, communication and networking devices). This limitation affects both companies with a dual nature such as Boeing or Airbus that develop civil and military airplanes, and companies with military-driven activities, such as L3 Technologies or Harris Corp. The limitation has already been pointed out in previous studies (Lee and Sohn, 2017; Schmid, 2017) but to the best of the author's knowledge, it has not been addressed[3].

Once the defence innovations have been identified, the empirical strategy requires a method to assess the dual use concept. Previous empirical works operationalized dual use through co-classification of IPC codes (Acosta et al., 2011; Acosta et al., 2017; Lee and Sohn, 2017): they distinguished between military patents (associated with military IPC codes only), civilian patents (associated with non-military IPC codes only), and mixed patents (patents with both military and civilian IPC codes). Acosta et al. (2017) and Schmid (2017) introduced the identification of a set of defence firms[4] in their empirical strategy in order to improve definition of the analysis' perimeter.

Starting from this data structure, scholars have also studied the diffusion of military technologies exploiting the patent citation network. Schmid (2017) applied the count of forward citations as a measure of diffusion with no distinction in the nature of the citing patents (military or civilian) since the aim was to compare the diffusion levels of the two types of innovations.

Other academics (Acosta et al., 2017; Lee and Sohn, 2017) further contributed by identifying the nature of citing patents (military or civilian) by studying knowledge diffusion with reference to the dual use of the innovations, continuing to apply the identification strategy based on military IPC codes. Acosta et al. (2017) found evidence that it is more likely to observe a diffusion of knowledge from military to civilian patents when the seed defence patent is associated with both military and civilian IPC codes. Lee and Sohn (2017) focused on the quality of the innovations (proxied by patent renewals) and found a positive relationship between the value of military technology and duality, measured as the ratio of forward citation by the civilian sector over the total number of citations. From a dataset of military patents belonging to Norwegian defence firms, Enger (2013) found that knowledge diffusion from military to civilian fields is positively related to collaboration with research organizations and to the technological scope.

2 Method for identifying defence innovations and dual use

2.1 General approach and goal of the study

The primary goal of the study is to produce quantitative evidence concerning the magnitude and specificities of dual use technologies and inform the policy making debate at EU level. The proposed analysis adopts a novel method based on the identification of military patents and then of dual use inventions, relying on citation flows.

[3] Schmid (2017) employed the classification provided by the Derwent Class Code 'W07' (Electrical Military Equipment and Weapons).

[4] Acosta et al. (2017) relied on the SIPRI database. Schmid (2017) started from a list of 50 firms and then limited the sample to those with at least 5% of their patents are military according to the classification provided by the Derwent Class Code 'W07' (Electrical Military Equipment and Weapons).

Based on patent data, this research will provide estimates of the size of the innovation activities in the defence and security sector, at least from what can be observed from disclosed sources. It is worth remembering that patents represent only a partial subset of innovations and in the case of defence inventions this limitation includes those patentable inventions that are kept secret due to their sensitive nature and in the interest of national security. However, patent data provides researchers with a large set of observations that can be studied bearing in mind the above-mentioned limitation. Previous studies have relied on alternative approaches based on case studies[5], which, however, do not allow for large scale and comprehensive analysis.

The method supports the mapping of dual use innovations through the identification of citation flows among patents. The approach is meant to evaluate the impact of spill-over effects under different perspectives:

- The presence of dual use patented inventions;
- The magnitude of spill-over effects outwards and inwards into and out of Europe for defence-only and dual use innovations;
- The magnitude of spill-over effects across relevant sectors for defence-only and dual use innovations.

2.2 Data source and scope

Patent documents were searched and identified in patent repositories. PATSTAT was relied on as a main repository, and Clarivate/Thomson Innovation as a support source of information. The searches covered the years from 2002 to the last usable data, based on the priority date of patents. The most recent years are underrepresented due to the patent publication non-disclosure window (18 months) and the lags in data provision. Consequently, the analyses will focus on the years until 2012, which is sufficient to perform a reliable citation analysis.

In terms of geographic scope, the primary focus of the study is to describe the economic impact of dual use in Europe (EU28). The methodological approach is therefore to conduct a global study and focus to all countries which are members of the EU area and a number of selected non-European countries which would also enable comparison and benchmarking.

The geographical scope of the queries considered the main patent offices: all the offices of the member countries of the EPC, EPO, USPTO, JPO, KIPO, and those of Canada, Russia, Israel, and India. Such an approach, although bearing some limitations in the scope and in the identification of military companies from certain areas (i.e. Chinese players), conveys a much more robust identification strategy when analysing firm names, corporate trees, and citation flows.

The collected patents were geo-localized according to the residence of the applicants and of the inventors. Geo-localization is based on the OECD REGPAT classification that provides information for Europe and for several other world countries at the finest level of NUTS[6]. The analysis was carried out on the subsample of EPO and WIPO patents that are available in REGPAT 2016, and the geographical information was aggregated at the level of patent families.

Concerning the selection of the defence companies, the lists available in the global Arms Industry Database developed by SIPRI and CERTIDER, which focuses on the EU member countries, were relied on.

[5] For example, see Hartley (2006).

[6] More information here: http://ec.europa.eu/eurostat/web/regions-and-cities/overview (last access in June 2018)

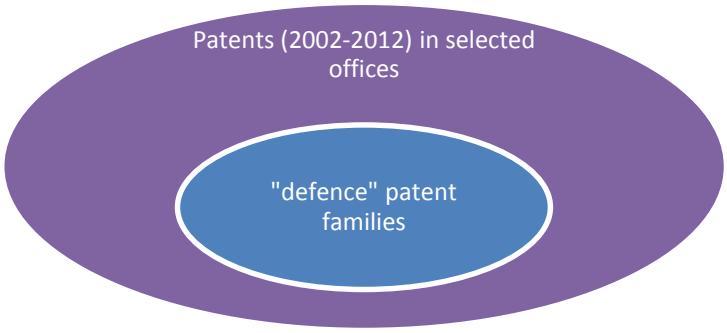
2.3 Method

In this section, details on the method used to identify dual use innovations were provided. The process was carried out by performing a consistency data check on the results of the defined search queries. The approach consists of a multistep method that relies on patent repositories as the data source:

- Step 1: Identification of defence innovations;
- Step 2: From patents to patent families;
- Step 3: Identification of dual use patents.

2.3.1 Step 1: Identification of defence innovations

The aim of this methodological step is to **identify the "defence" patents**. The defence and security industry encompasses a wide range of technological fields (including aeronautics, artificial intelligence, nanotechnologies, and nuclear research). Inventions and scientific advances, when disclosed, might not directly mention the application of the innovation in warfare: for instance, the description of an airplane engine is the same for both a civil and a military aircraft and its final application might not be specified. In addition, some of the largest corporations investing in defence and security research have both civil and military lines of business (e.g. Airbus, Honeywell International, General Electric).



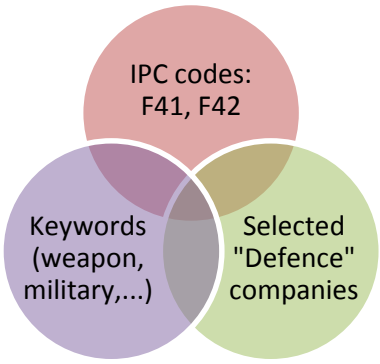
In trying to cope with these issues, the proposed methodology relies on a mixed approach to identify defence and security innovations. Patents were retrieved by combining searches on companies in SIPRI and CERTIDER, and on the technological classification (IPC codes) of patents.

Nevertheless, some limitations are still present due to the impossibility of obtaining fully certain identification of innovative activities in the defence sectors. On the one hand, the military or civil application of a specific invention is not necessarily included in the description of the invention itself: an attempt to overcome this problem is made by searching by company name. On the other hand, some companies operating in the defence sector are also active in non-military markets: hence, we integrate a selection criterion based on the description of the technology (through IPC codes and/or keywords). This approach is expected to exclude from the analysis those inventions with a potential military application that do not mention this as a function and are developed by companies without a clear focus on defence.

Our multi-criteria approach for the inclusion of an invention in the category defence relies on three criteria. Patents were tagged as pertinent to the defence sector if they satisfied at least one of the following requirements:

a) Presence of military IPC codes ("IPC criterion");
b) Assignee is a military firm ("firm criterion");
c) Patent text fields contain military-specific keywords ("keyword criterion").

Figure 1: Selection criteria used to access the patent database to identify of defence inventions



The proposed criteria defined the sample of "defence" inventions. As shown in Figure 1, some of the patents satisfy more than one admission condition.

The following paragraphs provide details for each criterion of inclusion.

a) Presence of military IPC codes

Patents are considered to be part of the "defence" sector if they are associated with any of the IPC codes that are military-specific. Table 1 reports the list of IPC codes identified in the literature (Acosta et al., 2011; Acosta et al., 2017) and new additional codes retrieved from the analysis of the IPC descriptions when defence related keywords are included[7].

The results from each search were checked manually in order to control for the presence of false positive records. To improve the accuracy of the queries, several exclusion criteria were applied. Patents satisfying any of the following conditions were not included in the result set:

- Patents of games, toys, or sport identified by keywords or IPC A63, "Sports; games; amusements";
- Patents about Airbag systems, identified by keywords (Airbag, seatbelt, pre-tensioner) or the contemporaneous presence of IPC F42 and either B60R 21 "Arrangements or fittings on vehicles for protecting or preventing injuries […]", or B60R 22 "Safety belts or body harnesses in vehicles";
- Company names including "airbag" or "toy".

[7] Two IPC codes were not included although containing defence related keywords in their description: A45B 3/14 ("Sticks with weapons") and G03B 29 ("Combinations of cameras, […] with non-photographic non-optical apparatus, e.g. clocks or weapons"). The manual screen of the associated patents show a predominance of civilian inventions.

Table 1: List of IPC codes selected as defence specific

Source	IPC code	Description
New	A45F 3/06	Travelling or camp articles; Sacks or packs carried on the body specially adapted for military purposes
Acosta et al. (2017)	A62D 101/02	Chemical warfare substances
New	B21D 51/54	Making hollow objects cartridge cases, e.g. for ammunition, for letter carriers in pneumatic-tube plants
New	B21K 21/04	Shaping thin-walled hollow articles, e.g. cartridges
New	B21K 21/06	Shaping thick-walled hollow articles, e.g. projectiles
New	B21K 21/14	Closed or substantially-closed ends, e.g. cartridge bottoms
New	B60R 7/14	Stowing or holding appliances inside of vehicle […] e.g. travelling articles, or maps. Disposition of racks, clips, or the like for supporting weapons
New	B63G	Offensive or defensive arrangements on vessels; mine-laying; mine-sweeping; submarines; aircraft carriers
New	B64D 1/04	Dropping, ejecting, releasing, or receiving articles, liquids, or the like, in flight …the articles being explosive
New	B64D 1/06	Dropping, ejecting, releasing, or receiving articles, liquids, or the like, in flight; Bomb releasing; Bomb doors
New	B64D 7	Arrangement of military equipment; Adaptations of armament mountings for aircraft
Acosta et al. (2017)	E04H 9/04	Buildings, groups of buildings, or shelters adapted to withstand or provide protection against air-raid or other war-like actions
Acosta et al. (2017)	E04H 9/08	Structures arranged underneath buildings, e.g. air-raid shelters
Acosta et al. (2017)	E04H 9/12	Entirely underneath the level of the ground, e.g. air-raid galleries
Acosta et al. (2017)	E06B 5/10	Doors, windows, or similar closures for special purposes; Border constructions for protection against air-raid or other war-like action
	F41	Weapons
	F42	Ammunition; Blasting
New	G01S 1/42	Conical-scan beam beacons transmitting signals […], e.g. for "beam-riding" missile control
New	G01S 19/18	Satellite radio beacon positioning systems; Determining position, velocity, or attitude using signals transmitted by such systems. Military application
New	G06G 7/80	Analogue computers for specific processes, systems, or devices, e.g. simulators; for gun-laying; for bomb aiming; for guiding missiles

b) Assignee is a military firm

Patents are included in the dataset when they belong to the portfolio of a company that mainly operates in the defence sector. The identification of companies dealing with military products relies on two main sources: the SIPRI Arms Industry Database[8] and the Register of the Certified Defence-related Enterprises (CERTIDER)[9].

The SIPRI database contains more than 200 unique firms with different levels of involvement in the defence business. The dataset provides information on the value of arms sales. The ratio of arms sales on the total sales is a suitable selection criterion for including the patent portfolio of the corresponding firm. From the analysis of the listed companies, 50% were identified as threshold level which will serve as parameter

[8] The SIPRI arms industry database contains information on the 100 largest arms-producing and military services companies and it is publicly available at: https://www.sipri.org/databases (last accessed in October 2017)

[9] The register includes more than 50 European companies and is available from: http://ec.europa.eu/growth/tools-databases/certider/index.cfm (last accessed in October 2017)

of inclusion: firms with at least half of their revenues derived from arms sales are labelled "defence" firms, and accordingly all their patents.

Public online information on the business activities of the companies was controlled to perform a robustness check for the selected threshold. The consistency check led to the exclusion of two companies (United Engine Corp., Rockwell Collins); although deriving slightly more than 50% of their revenues from arms sales, their activities seem particularly "mixed". At the same time, two additional companies were included even though their arms sales are below the 50% threshold, Uralvagonzavod and Oshkosh since their business and their innovation activities appear to be mainly focused on defence.

In several cases of firms showing "mixed" (civil and military) activities, defence subsidiaries or business units could be separated (as in the cases of Diehl, Meggit, and Snecma).

The process led to the selection of 149 firms from the SIPRI database.

The approach avoids the inclusion of two types of false positive results:

1. Large corporations active in several businesses and technological fields (e.g. General Electric) for which only a small fraction of patents in the portfolio may be related to military activities.
2. Vehicles such as aircrafts, helicopters, and ships have a dual use by nature since they can be used in both warfare and in civil applications (transportation of goods and people, rescue, medical assistance). The method led to the inclusion of those firms developing innovations for the military sector and the exclusion of companies such as Boeing or Airbus (military specific inventions are included from the application of the other selection criteria).

Concerning the 45 firms in the CERTIDER list, nine companies showing a portfolio of "mixed" activities were excluded. Another seven firms did not file patents in the time frame considered. The final list of patenting companies from CERTIDER contains 29 entities.

The names of the companies selected from SIPRI and CERTIDER were searched in the assignee field of the patent database. The queries considered potential name changes, spelling errors, acronyms, etc.

Judging from the preliminary analyses, it was decided to include additional firms and government agencies by searching for the following keywords in the field "assignee name": defence, tactical, weapon, armoured vehicle, ammunition, army/navy/air forces, (synonyms and variations included)[10]. This search criterion allowed the identification of the largest patent portfolio holders among government agencies and ministries (e.g. US Navy, Agency for Defence Development of South Korea, Canadian Minister of National Defence, Japan Ministry of Defence).While performing the searches, the retrieved assignee names were screened to avoid the inclusion of companies with similar names. As a robustness control, the main IPC codes in their patent portfolios were examined to verify the attribution in terms of industry coverage.

c) Patent text fields containing military specific keywords

The database of defence patents is enriched by those containing a selection of keywords associated to the "defence" sector. The patent documents in the main text fields were searched (title, abstract and claims). The list of keywords is shown in Table

[10] Some terms were excluded from the results (e.g. "medical", "la defense", "health", and other specific confounding terms were considered to be stopwords in the assignee name).

2. Each concept was searched by controlling for stemming and different spelling. The results were tested in order to check for false positive results[11].

Table 2: List of concepts and keywords searched for in patent text fields. Decision on inclusions/exclusion as selection criterion for the defence patent database

Keyword	Searched text fields	Decision from preliminary checks
Military	Title Abstract	Included
War, warhead, warfield, combat		Excluded (identifies non-military inventions); e.g. "warhead" is used in metal industry
Warfare, warzone, battlefield, battlezone	Title Abstract	Included
Tactical	Title Abstract Claims	Included but in combination with Stopwords (e.g. "business", "portfolio", "finance" or "patient")
Weapon, missile, landmine, grenade	Title Abstract	Included
Torpedo		Excluded (identifies non-military inventions); e.g. torpedo automobile
Bulletproof, ammunition, ordnance, firearm, smallarm	Title Abstract	Included
Armour, gun, bullet, shotgun		Excluded (identifies non-military inventions); e.g. gun used for painting or glue
Ballistics + (armour or projectile or gun or bullet)	Title Abstract	Included
Camouflage		Excluded (identifies non-military inventions); e.g. apparel
Blast shield		Excluded (identifies non-military inventions); e.g. used in furnaces
Turret, cannon		Excluded (identifies non-military inventions); e.g. any type of turrets
Countermeasure		Excluded (identifies non-military inventions); e.g. any type of countermeasure
Surveillance		Excluded (identifies non-military inventions); e.g. any type of surveillance
Kevlar, nomex, or technora		Excluded (identifies non-military inventions); e.g. civilian equipment

The searches excluded those patents covering board games and other type of games from the results (IPC class A63 "Sports; Games; Amusements"; keywords in the title, abstract or claims: "game", "toy", "sport"). Keywords related to "chemical warfare" have not been directly searched since many of the chemical compounds also have industrial and medical applications. Similarly, those keywords which might specifically define «cyberwar» were excluded since they produce a high number of false positive results.

2.3.2 Step 2: From patents to patent families

Once patents had been labelled with the "defence" tag, a more accurate level of analysis was introduced and INPADOC patent families were considered (a collection of patent documents covering an innovation) instead of individual patents. Patent families are considered to be a more precise measure of inventive activities and allow duplications to be avoided when working with patent documents from multiple offices.

[11] Some examples: words such as "tank" or "defence" are not included since they lead to a significant number of civilian patents; similarly, when searching for "warhead", some of the resulting patents cover inventions not related to military applications (erg. patent "US8569005B2" about peptides and molecular reactions) while all those referring to missiles are included through IPC codes or the keyword "missile". Another example of misleading search is the use of "militar*": it returns patents about *Cordyceps Militaris*, a type of mushroom.

The process led to the identification of "defence" patent families. The use of families also helps drawing a more accurate representation of the patent citation network that we will use to operationalize the definition of dual use (see the next step).

2.3.3 Step 3: Identification of dual use patents

The methodological approach focuses on dual use patents, defined as defence inventions cited by subsequent non-military ones (from military to civil technologies). However, for a selected cohort of recent innovations, a specific analysis was also performed in order to identify the reverse direction, that is to say, when defence innovations are derived from previous non-military ones (from civil to military inventions).

This step aims to identify those patents in the "defence" patents selected in the first stage with a potential dual use. Our operationalization of the definition of "dual use" relies on the patent citation network. The proposed approach is expected to improve the previous methods based on the co-occurrence of a limited number of IPC codes considered to be "defence-specific" (mainly F41 and F42) with any other IPC code[12].

From the examination of the patent citation network, the two potential directions of dual use were distinguished: i) from a military to a civil invention, and ii) from a civil to a defence innovation.

The first type was identified by looking at the citations received (forward citations) by the patents in the sample retrieved from previous steps[13]. If a "defence" patent family is cited by at least one non-defence subsequent invention, it was considered to be a dual use case (Figure 2). From the analysis of the preliminary results of dual use cases, it was decided to apply a strict rule in the identification strategy in order to avoid false positive cases of dual use innovations. A single defence invention is considered to be dual use when at least one of its forward citations is not part of the sample of the defence innovations and is not assigned to any of the companies listed in the SIPRI database. This means that a citation from a firm with a small fraction of sales from armaments (below the threshold for the inclusion in the starting defence database) is not sufficient to have the focal innovation considered as being dual. By way of example, the patent "US7077528B1", filed by Raytheon, is included in the defence innovation database since the assignee is a company with a ratio of arms sales above the selected threshold of 50%. Similarly, patents of Mitsubishi Electric Corp are not included since the company has only a limited share of arms sales. The patent "US7077528B1" has received several citations and one of them from the patent "US8113661B2", belonging to Mitsubishi Electric Corp: such subsequent utilization is not considered to be a dual use case.

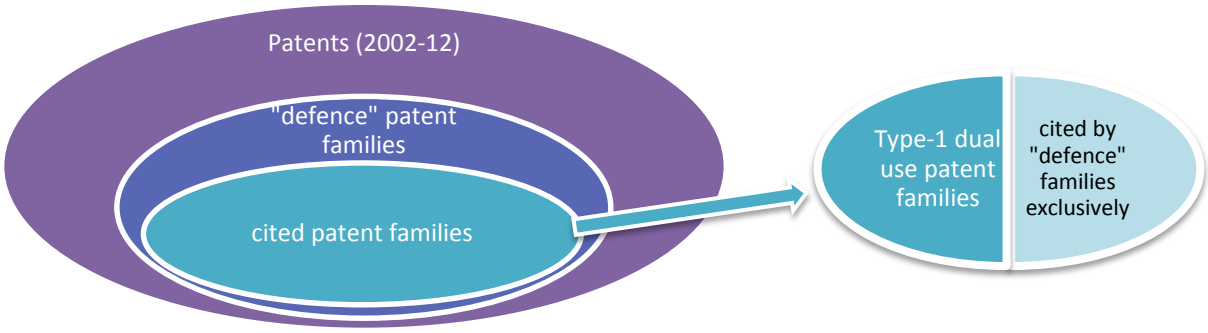
It is important to highlight the limits of the proposed identification method. By definition, only the "defence" patent families with at least one forward citation represent a potential subsample of dual use innovations. For those inventions with no subsequent patented developments, it is assumed that no further application (either of the defence or the civilian type) has been introduced. It is clear that neither all the innovations are patented nor a civilian application of a patented defence invention is

[12] The co-occurrence would simply describe the different technical elements included in the description of the protected inventions. By way of example, the co-classification approach will consider all those patents reporting F41 ("Weapons") and G02 ("Optics") as dual use inventions. Among those patents, a large number focuses on missile seekers, guidance systems, and weapon targeting tools for which a civil application, if possible, is expected to require a substantial modification and this is more likely to be embedded in a new patent application.

[13] Forward citations are those received from subsequent filings which mention the focal patent among their prior art. For each family, all of the forward citations received by any members in the patent family were traced.

necessarily worthy of being a new patent filing (in terms of technical novelty or economic profitability).

Figure 2: Diagram summarising the process for the identification of dual use families
(From defence to civil applications)



The proposed method relies on the classification of patents in terms of IPC codes, therefore on the work of patent examiners. It is assumed that the IPC codes associated to a patent are the result of a consistent and coherent process. There might be some noise as the same examiner might assign a different set of IPC codes to similar patents.

Further research could improve the identification of dual use cases starting from the proposed method. In fact, some specific technological fields (or products) are more likely to suffer from inconsistent IPC association[14].

Moreover, since the presence of forward citations is a common measure of the technical merit of a patent, the employed method searches dual use innovations only among those patents that were useful for one or more subsequent inventions: this is consistent with the ultimate meaning of "dual use", i.e. more than one use.

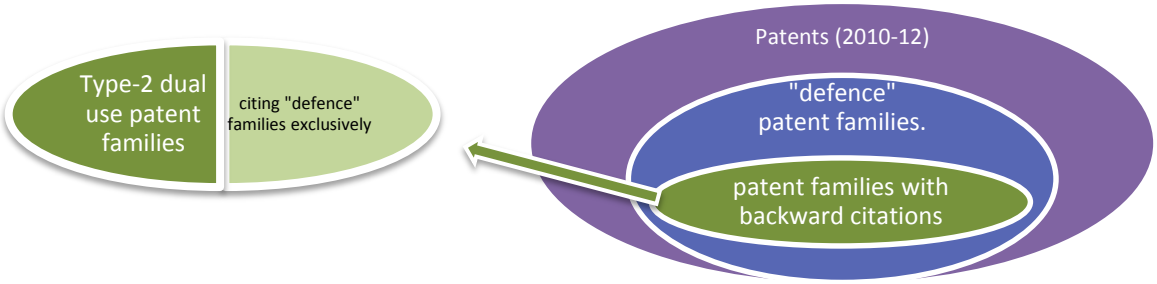
The second type of dual use, from civil to defence innovation, has been assessed by considering the backward citations[15]. In this case (Figure 3) the investigation focused on a subsample of recent patents (priority year between 2010 and 2012). This choice avoids the exclusion of too many elements of prior art. Please note that this operationalization is limited to the time frame examined: for those cases when all the backward citations have a priority year that falls outside the considered interval (2002-2012), their nature cannot be assessed (defence or civilian).

[14] Examples: Unmanned Aerial Vehicles (UAV) are mainly intended for military operations but, similar to the cases of airplanes and helicopters, no defence IPC code or keyword are necessarily associated with the corresponding inventions (even more for all of the structures and additional elements that complement them, such as slingshot); paintball arms and wearables, bows, and other weapon-like objects can be associated to F41/F42 and/or A63 codes: this causes improper behaviour.

[15] Backward citations are those included in each patent filing and form its prior art. For each family, all of the backward citations associated to any member in the patent family are traced. By definition, the examined subsample consists of the "defence" patent families with at least one backward citation.

Figure 3: Diagram summarising the process for the identification of dual use families

(From civil to defence applications)



2.4 Details on selected technologies

In terms of industries, the primary focus of the study is to identify the defence and security innovations from a broad perspective. Hence, the data at an aggregate level were analysed first, without distinguishing between technological fields. In addition, several vertical analyses on subsamples of specific technologies along two different clustering methods have been performed.

The first clustering describes the entire technological space in accordance with the WIPO-IPC concordance table[16] grouping the IPC codes into 35 technological fields. This approach allows mapping of all of the patents identified.

The second clustering considers 11 technological groups identified from the IPC codes and based on the relevance of specific technical fields in the traditional defence industry (e.g. Weapons and Transport/Vehicles) and of certain key technologies as acknowledged by the EC within the so called key enabling technologies (KETs). The groups are:

1. Weapon and ammunition (F41 "Weapons", F42 "Ammunition; Blasting").
2. Transport/vehicles: Aircraft and aeronautics (B64B "Lighter-than-air aircraft"; B64C "Aeroplanes; Helicopters"; B64D "Equipment […]"; B64F "Ground or Aircraft-Carrier-Deck Installations […]").
3. Transport/vehicles: Ships (B63 "Ships or other waterborne vessels).
4. Transport/vehicles: Railways, land vehicles, and others (B60 "Vehicles in general"; B61 "Railways"; B62 "Land vehicles […]").
5. Aerospace (B64G "Cosmonautics […]").
6. Nanotechnology (the correspondence to IPC codes is provided in EC, 2012).
7. Photonics (the correspondence to IPC codes is provided in EC, 2012).
8. Biotechnology (the correspondence to IPC codes is provided in EC, 2012).
9. Advanced materials (the correspondence to IPC codes is provided in EC, 2012).
10. Micro- and nano-electronics (the correspondence to IPC codes is provided in EC, 2012).
11. Advanced Manufacturing Technologies for other KETs (the correspondence to IPC codes is provided in EC, 2012, and in Gkotsis and Vezzani, 2016).

[16] Available here: http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/xls/ipc_technology.xls.

3 Description of the data

3.1 Composition of the Database of defence innovations

Application of the methodology described generated a final dataset of 177,143 patents which correspond to 63,714 patent families representing the innovations developed during the years 2002-12[17].

Table 3 provides details of the distribution of the records collected across the main methodological criteria: each patent is either owned by a defence company, is associated to a military IPC code, or includes defence specific keywords. Although there is a non-negligible overlapping across the entry criteria, the choice of the different selection conditions contributes to an incremental way to generate the database.

The largest contribution comes from the application of the "firm" criterion: 43% of the patent families are owned by defence firms which, at the same time, do not report military-specific IPC codes or keywords. The inclusion of inventions with defence IPC codes only contributes 27% of families to the sample. Finally, inventions that are not included in the "firm" or "IPC" criteria, but are associated with the "keyword" criterion, represent 5% of the database. This suggests that this criterion provided a limited marginal contribution in the creation of the sample of defence patents.

Concerning the overlapping across the proposed criteria, "IPC" and "keyword" share 10% of the total database, while "firm" and "IPC" about 8%. Only about 3% of the inventions identified satisfy the three conditions at the same time.

Table 3: Description of the database according to the application of the selection criteria used

Selection criteria			Patents	Perc on tot. patents	Patent Families	Perc on tot. patent families
firm	IPC	keyword				
Y	Y	Y	6194	3%	2399	4%
Y	Y	N	13434	8%	3434	5%
Y	N	Y	1299	1%	658	1%
N	Y	Y	17676	10%	9010	14%
Y	N	N	86722	49%	27646	43%
N	Y	N	45459	26%	17182	27%
N	N	Y	6359	4%	3385	5%
Total			177143	100%	63714	100%

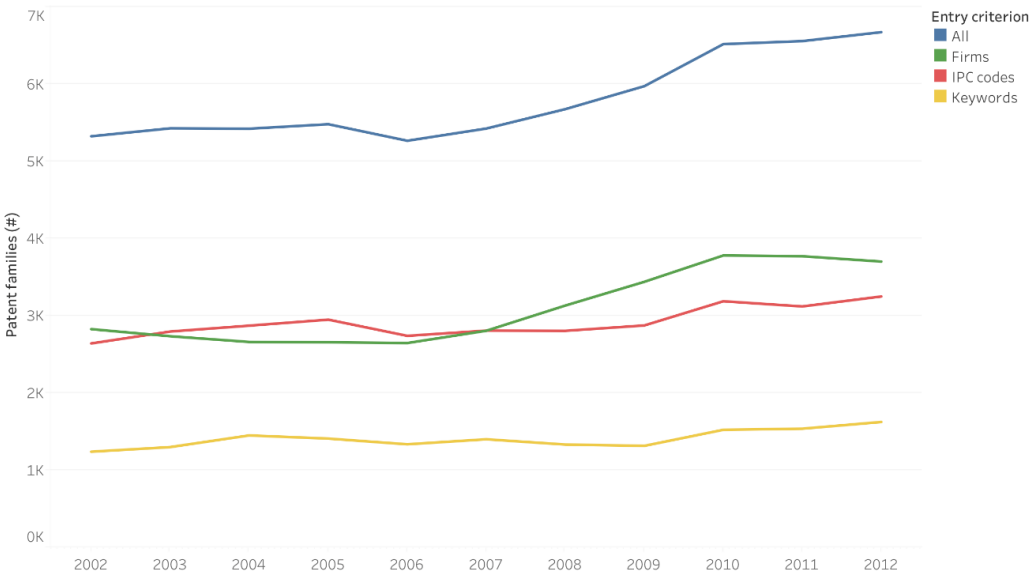
3.1.1 Time trend

The number of patent families per year in the sample of defence innovations increased by 25.3% in the years between 2002 and 2012; the largest part of the growth (23.0%) occurred between 2006 and 2010 (Figure 4). Interestingly, the growing trend in patent families during these 5 years seems to be driven relatively more by the sample of military inventions captured through the entry criterion based on firm names (32.0%) whereas the number of patent families filed per year and identified as a means of IPC codes (15.8%) and keywords are more stable through time (16.0%).

This result seems to suggest that defence companies are continuously and increasingly innovating, especially in technological fields that are not strictly identified with specific IPC codes or military-related keywords.

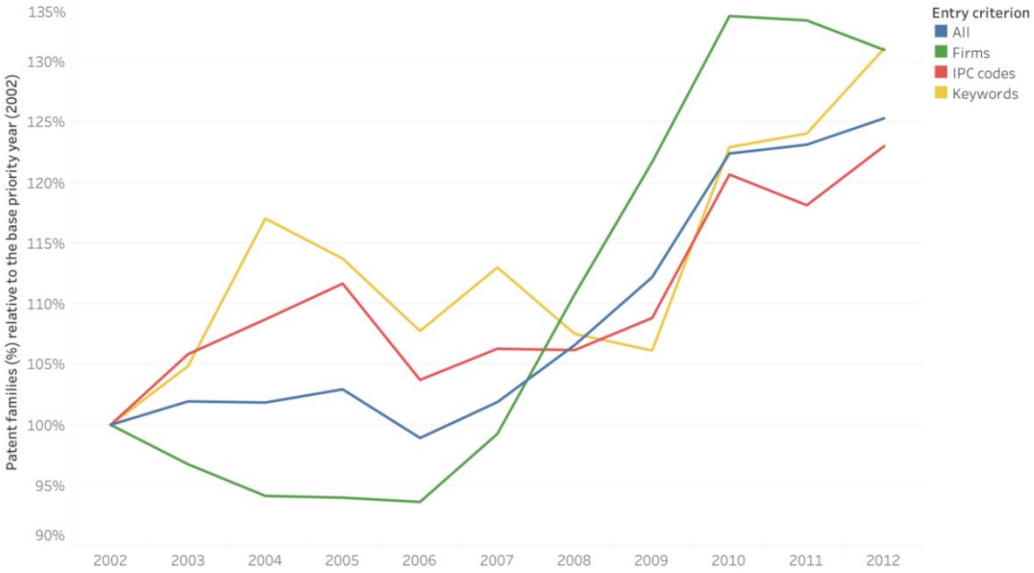
[17] Note: 3,291 patents do not have Family ID (1.9%).

Figure 4: Patent families by priority year, details by entry criterion



These dynamics can be further explored by looking at the number of patent families in percentage relative to a base priority year, in this case the beginning of the period analysed (2002) in Figure 5. The sub-samples built with IPC codes and keywords always exhibit a ratio of patent filings relative to the base year greater than one. In other words, the number of new inventions filed each year has increased compared to to the base priority year.

Figure 5: Families by priority year as percentage of 2002 value, details by entry criterion



On the contrary, the sub-sample of patent families identified through the firm name criterion has a lower index number than one in the first half of the period (before 2007) and higher than one in the following years (after 2007).

The changes observed in patent filings may be due to the entry of new players in the defence sector, a higher propensity to patent, or a sustained increase in the

innovation activities of the incumbent firms who are experienced in military product development.

3.1.2 Geographical scope

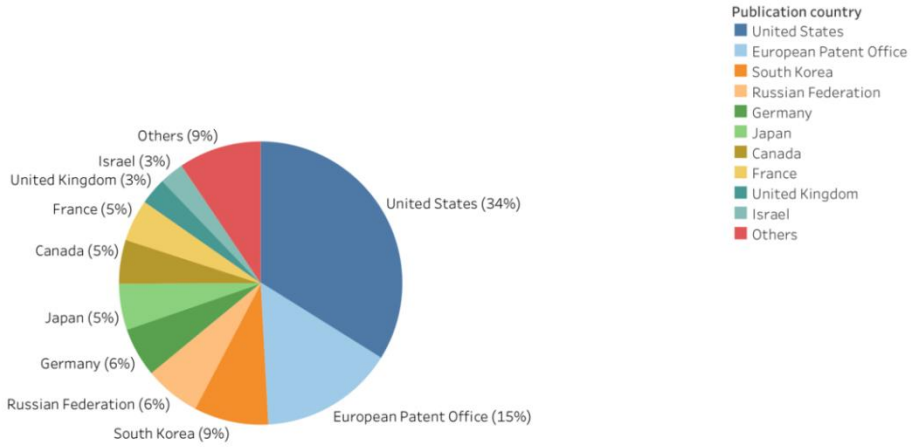
The geographical scope of the patent families in the sample of defence innovations are analysed in this section by studying both their publication and priority countries. It is worth remembering that the scope of publication countries is driven by the collection method that focuses on a selection of the most relevant world patent offices, with the exclusion of the Chinese one[18].

Sections 3.2.1 and 3.2.2 provide further information based on the addresses of the inventors and the applicants for the subset of patents filed at the EPO by leveraging the regional data available in the OECD REGPAT database.

The publication countries represent the destination markets where patent protection has been sought, and so where the applicants have an interest. Defence patent families have been filed in 1.67 countries on average: 72% of patent families only have 1 publication country (office), 9% have 2 countries, 8% have 3 countries, 5% have 4 countries, and 5% have 5 or more countries.

The first five offices by relative occurrence in the sample of defence innovations – the USA, EPO, South Korea, Russian Fed., and Germany – represent 70% of all publications (Figure 6). More than half (56.5%) of all patent families have been published in the USA whereas a quarter (25.4%) of all inventions have been extended at the EPO (Table 4). More in detail, it can be observed that Germany, France, and UK are the most frequent publication countries in Europe, whereas South Korea, Russia, Japan, Canada, and Israel are the most common ones in other regions of the world.

Figure 6: Share of publication countries for the sample of defence patent families identified (2002-2012)



[18] From preliminary searches, the application of the proposed identification method on Chinese patents and Chinese company names would have introduced a high level of complexity in the treatment of the data collected due to translation issues and the presence of false positive or negative results. Consequently, the filings at the Chinese National Intellectual Property Administration were excluded. Although this choice reduced the scope of the analysis, it aims to maximise the consistency of the data collected and the evaluation of the magnitude of dual use innovations.

The analysis of the evolution of the number of filings at the selected publication offices reveals information on the destination markets. Compared to 2002, data for 2012 show a significant increase in the volume of patent families at the offices of: South Korea (+199%), France (+68%), Canada (+14%), Russian Federation (+20%), and the USA (+15%). On the contrary, a reduction occurred in the offices of: Germany (-57%), Japan (-38%), and the UK (-25%).

The aggregated data for European offices shows a decline in their relative share (from 26% to 17%). This variation is balanced by the concomitant increase of patent filings at the EPO (+21%).

Table 4: The top 20 publication offices by number of defence patent families (2002-2012)

Rank	Publication country	Families	Perc.
1	USA	35,997	56.5%
2	EPO	16,196	25.4%
3	SOUTH KOREA	9,078	14.2%
4	RUSSIAN FED.	6,714	10.5%
5	GERMANY	6,029	9.5%
6	JAPAN	5,554	8.7%
7	CANADA	5,365	8.4%
8	FRANCE	5,012	7.9%
9	UK	3,319	5.2%
10	ISRAEL	2,893	4.5%
11	SPAIN	2,878	4.5%
12	AUSTRIA	2,389	3.7%
13	ITALY	731	1.1%
14	POLAND	638	1.0%
15	NORWAY	588	0.9%
16	DENMARK	553	0.9%
17	SWEDEN	338	0.5%
18	INDIA	247	0.4%
19	PORTUGAL	244	0.4%
20	FINLAND	196	0.3%
	OTHERS	1,216	1.9%

The priority country represents the origin of the innovation, and it can be considered as a proxy of where the research was carried out. The USA, South Korea, the Russian Federation, France, and Germany are the most frequent priority countries by relative occurrence in the sample of defence innovations. These countries represent approximately 80% of defence inventions (Table 5). Almost 45% of patent families were initially filed in the US whereas only 2% of the selected inventions have a priority at the EPO. France, Germany, the UK, Italy, Poland, Sweden, Spain, Finland, and Austria are the most frequent priority countries in Europe and represent nearly 23% of the sample in terms of patent families.

Table 5: The top 20 priority offices by number of defence patent families (2002-2012)

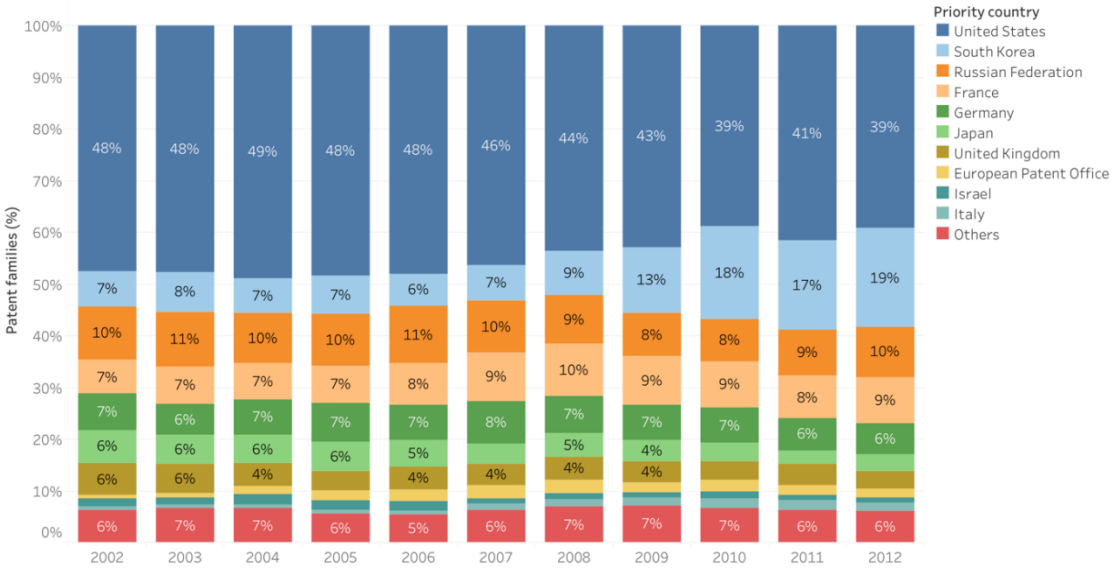
Rank	Priority country	Families	Perc.
1	USA	28,338	44.5%
2	SOUTH KOREA	7,053	11.1%
3	RUSSIAN FED.	6,147	9.6%
4	FRANCE	5,285	8.3%
5	GERMANY	4,370	6.9%
6	JAPAN	2,863	4.5%
7	UK	2,753	4.3%
8	EPO	1,171	1.8%
9	ISRAEL	891	1.4%
10	ITALY	757	1.2%
11	WIPO	714	1.1%
12	POLAND	446	0.7%
13	SWEDEN	329	0.5%
14	SPAIN	301	0.5%
15	CANADA	236	0.4%
16	FINLAND	200	0.3%
17	AUSTRIA	159	0.2%
18	AUSTRALIA	152	0.2%
19	TURKEY	125	0.2%
20	TAIWAN	111	0.2%
	OTHERS	1,313	2.1%

The analysis of the evolution of the geographical origin of defence innovations highlights the increasing proportion of innovations having South Korea as the origin country and a relative decrease in the share of inventions originating from the USA (Figure 7).

Compared to 2002, data for 2012 shows a significant increase in the volume of patent families at the offices of: South Korea (+258%), Italy (+172%), France (+70%), and the Russian Federation (+18%). On the contrary, there was a reduction in the offices of: Japan (-35%), and the UK (-33%).

Concerning the European countries, 24.1% of all the defence inventions have a first priority in one of them, and the amount has been increasing through time (+17%).

Figure 7: Relative share of priority offices across years (priority year)



3.2 Defence innovation activities at national and regional levels

The intensity of the patenting activities of the defence companies in the identified sample is described in this section, focusing on the regional level. This analysis relies on the geo-localization data available in the OECD REGPAT database. The standardized classification is provided for the subset of EPO patents: so the data is expected to show a bias towards the European innovators, which are more likely to file patents at the EPO. However, due to the relevance and the regional nature of this patent office, which acts as an entrance point to the EU patent systems, non-European patent applicants are expected to show a non-negligible presence.

Data on the residence countries of applicants is useful in highlighting the different patent filings and market allocation strategies of firms active in the defence industry (OECD Patent Statistics Manual, 2009). Focusing on the residence address of inventors provides a more accurate identification of the *loci* of invention, reducing the noise in the data deriving from corporate strategies that may centralize the filing procedure with no regards to the localization of the subsidiary or of the research laboratory that actually developed the innovation.

3.2.1 Localization of applicants

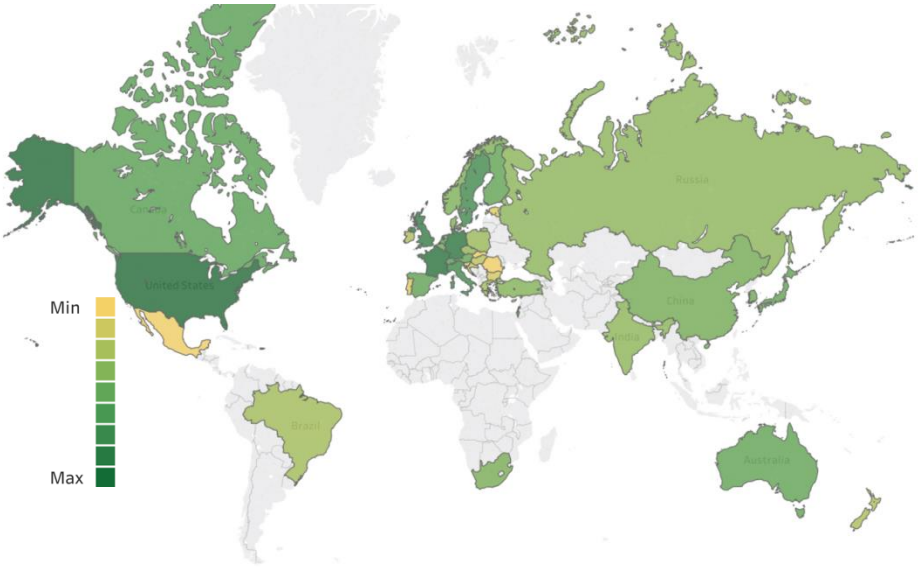
Before presenting the results of patenting intensity at regional level (NUTS 2), a description at country level is provided for the purpose of comparison with the results of the analysis of the priority countries previously discussed. Some countries are not so well represented in relative share (e.g. South Korea, the Russian Federation) since applicants in those countries are less likely to extend the patent protection to the EPO.

The USA, France, Germany, the UK, and Italy are the five most frequent applicant countries in the sample of EPO defence innovations, representing almost 84% of all residence countries of the patent owners (Table 6 and Figure 8). More than 35% of all patent families have an applicant located in the USA, 20% in France, and approximately 16% in Germany. More than 56% of the patent owners recorded in the EPO filings are located in a European country. Israel, Switzerland, Canada, Japan, Australia, South Korea, China, and South Africa are other frequent applicant countries from outside the EU.

Table 6: The top 20 residence countries identified from the applicants' residence addresses
(For the sub-sample of EPO patents)

Rank	Applicants' country	Families	Perc.
1	USA	5,617	35.6%
2	FRANCE	3,168	20.1%
3	GERMANY	2,505	15.9%
4	UK	1,510	9.6%
5	ITALY	594	3.8%
6	SWEDEN	566	3.6%
7	ISRAEL	409	2.6%
8	SWITZERLAND	150	1.0%
9	CANADA	144	0.9%
10	NETHERLANDS	134	0.8%
11	SPAIN	110	0.7%
12	JAPAN	106	0.7%
13	AUSTRALIA	104	0.7%
14	FINLAND	100	0.6%
15	AUSTRIA	99	0.6%
16	SOUTH KOREA	72	0.5%
17	BELGIUM	62	0.4%
18	CHINA	60	0.4%
19	SOUTH AFRICA	52	0.3%
20	NORWAY	43	0.3%
	OTHERS	271	1.7%

Figure 8: Map of applicants' countries for the sub-sample of EPO patents in REGPAT



The following table (Table 7) and Figure 9 reports the results of the analysis of the localization of applicants at the regional level (NUTS2). The Île de France (17% of EPO defence patents), the London area (5%), and the Oberbayern region of Germany (4%) are the most represented regions in Europe when analysing the applicants' addresses

while Massachusetts (9%), California (6%), and Florida (5%) are the most frequent regions in the USA (Figure 10). Of the top 20 regions, 8 are located in the USA, 6 in Germany, 2 in France, and 1 respectively in the UK, Sweden, Italy, and Israel.

Table 7: The first 20 residence regions (NUTS2) identified from applicant residence addresses
(For the sub-sample of EPO patents)

Rank	Applicants' region	Country	Families	Perc.
1	ÎLE DE FRANCE	FR	2,755	17.5%
2	MASSACHUSETTS	US	1,383	8.8%
3	CALIFORNIA	US	881	5.6%
4	INNER LONDON	GB	820	5.2%
5	FLORIDA	US	718	4.6%
6	OBERBAYERN	DE	666	4.2%
7	MARYLAND	US	465	2.9%
8	ÖSTRA MELLANSVERIGE	SE	449	2.8%
9	TEXAS	US	429	2.7%
10	SCHLESWIG-HOLSTEIN	DE	338	2.1%
11	LÜNEBURG	DE	255	1.6%
12	CONNECTICUT	US	241	1.5%
13	BERLIN	DE	226	1.4%
14	BREMEN	DE	213	1.4%
15	VIRGINIA	US	212	1.3%
16	LOMBARDY	IT	207	1.3%
17	HAIFA DISTRICT	IL	188	1.2%
18	RHÔNE-ALPES	FR	156	1.0%
19	FREIBURG	DE	152	1.0%
20	NEW YORK	US	151	1.0%
	OTHERS		5,373	34.1%

Figure 9: Map of applicants' regions (NUTS2) in EU for the sub-sample of EPO patents in REGPAT

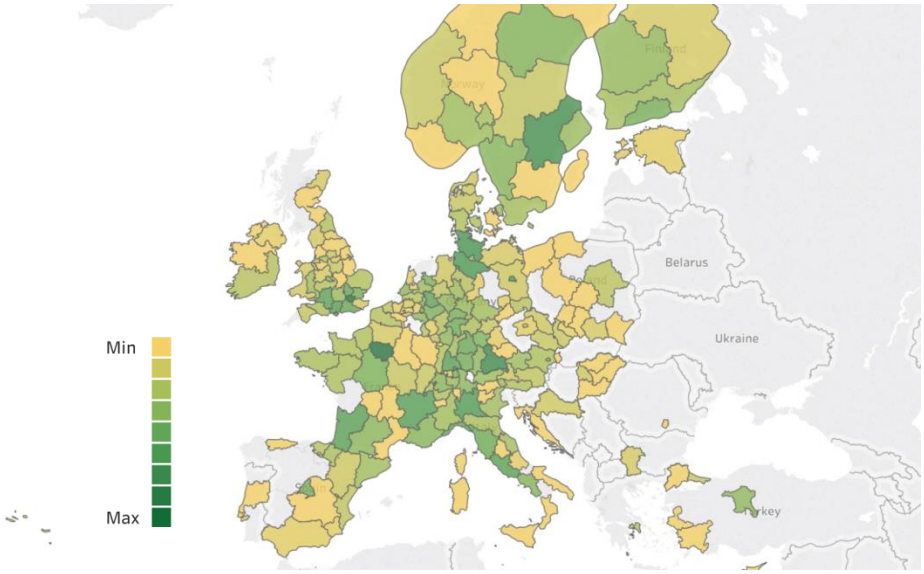
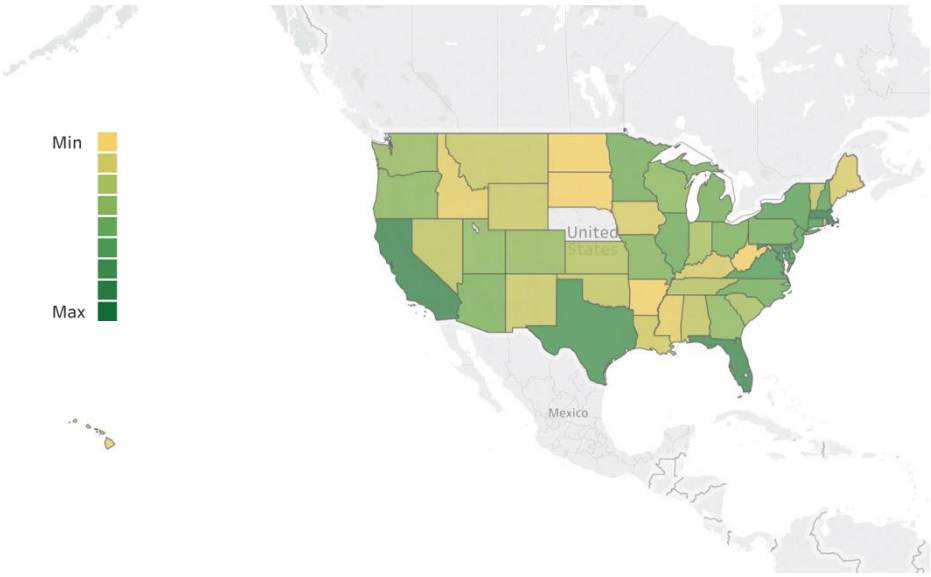


Figure 10: Map of applicant regions (NUTS2) in the USA for the sub-sample of EPO patents in REGPAT



3.2.2 Localization of inventors

The localization of inventors indicates the inventiveness of the laboratories and labour force in a given geographical area. The address given in the patent document is usually the professional or the residential address of the inventor.

Similar to the previous evidence on the whole sample of defence innovations, the subsample of EPO patents shows that most of the patent families are from US based inventors (35.7%) (Table 8 and Figure 11). The USA, France, Germany, the UK, and Italy are the most recurrent inventor countries in the sample of defence innovations and represent 84% of all residence countries. Apart from 36% of all the selected patent families which have an applicant located in the USA, 20% have an applicant in France, and 16% in Germany. Approximately 57% of the selected patent families have an inventor with residence in the EU.

The most frequent countries of origin of innovations from outside the EU are Israel, Canada, Switzerland, Japan, Australia, South Korea, South Africa, and China.

The amount of defence inventions for each country, allocated through the address of the applicant(s) or the inventor(s), are very similar. This suggests that defence R&D activities are mainly localized near the headquarters and confirms previous findings about the Aerospace and Defence sector (Gkotsis and Vezzani, 2016).

The proportion of military patent families with at least one inventor located in the USA and UK is decreasing through time, respectively from 41.6% to 31.1% and from 11.3% to 8.6% (Figure 12). Conversely, the relative number of patent families with inventors located in France and Germany is increasing through time.

Among the top 20 geographical origins at the regional level (NUTS2), only five countries are represented: US, France, Germany, Sweden, and the UK. The top 20 regions by number of inventions in the EPO sample represent one third of total defence innovations (Table 9).

Table 8: The top 20 residence countries identified from the inventor residence addresses
(For the sub-sample of EPO patents)

Rank	Inventors' country	Families	Perc.
1	USA	5,611	35.7%
2	FRANCE	3,220	20.5%
3	GERMANY	2,570	16.3%
4	UK	1,489	9.5%
5	ITALY	604	3.8%
6	SWEDEN	558	3.5%
7	ISRAEL	407	2.6%
8	CANADA	201	1.3%
9	AUSTRIA	141	0.9%
10	SWITZERLAND	140	0.9%
11	NETHERLANDS	132	0.8%
12	SPAIN	122	0.8%
13	JAPAN	112	0.7%
14	FINLAND	108	0.7%
15	AUSTRALIA	107	0.7%
16	BELGIUM	77	0.5%
17	SOUTH KOREA	72	0.5%
18	SOUTH AFRICA	61	0.4%
19	CHINA	56	0.4%
20	NORWAY	43	0.3%
	OTHERS	315	2.0%

Figure 11: Map of inventor countries for the sub-sample of EPO patents in REGPAT

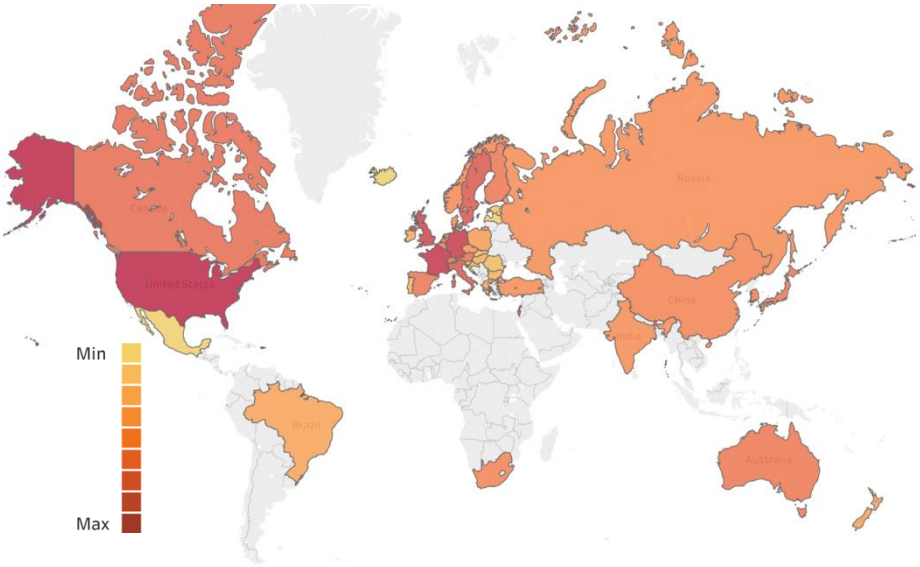


Figure 12: Relative share of patent families by priority year and inventor country of residence
(For the sub-sample of EPO patents in REGPAT)

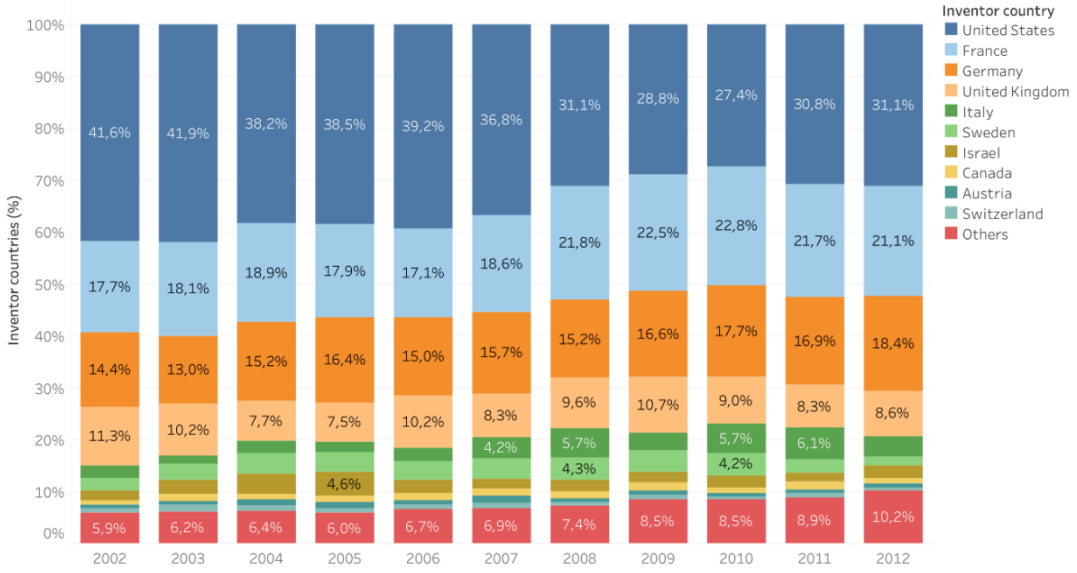


Table 9: The top 20 residence regions (NUTS2) identified from the applicant residence addresses
(For the sub-sample of EPO patents in REGPAT)

Rank	Inventor region	Country	Families	Perc.
1	ÎLE DE FRANCE	FR	1,761	11.2%
2	CALIFORNIA	US	1,430	9.1%
3	TEXAS	US	817	5.2%
4	FLORIDA	US	610	3.9%
5	OBERBAYERN	DE	509	3.2%
6	NEW YORK	US	410	2.6%
7	VIRGINIA	US	389	2.5%
8	MASSACHUSETTS	US	382	2.4%
9	ARIZONA	US	369	2.3%
10	SCHLESWIG-HOLSTEIN	DE	346	2.2%
11	MARYLAND	US	344	2.2%
12	ÖSTRA MELLANSVERIGE	SE	322	2.0%
13	GLOUCESTERSHIRE, WILTSHIRE, BRISTOL-BATH	GB	319	2.0%
14	CENTRE	FR	306	1.9%
15	MIDI-PYRÉNÉES	FR	299	1.9%
16	AQUITAINE	FR	297	1.9%
17	LÜNEBURG	DE	272	1.7%
18	FREIBURG	DE	262	1.7%
19	PROVENCE-ALPES-CÔTE D'AZUR	FR	255	1.6%
20	RHÔNE-ALPES	FR	243	1.5%
	OTHERS		9,853	62.6%

Figure 13 and Figure 14 map the presence of defence innovations in European and US regions (NUTS2) according to the location of inventors as reported by OECD REGPAT.

Figure 13: Map of inventor regions (NUTS2) in Europe for the sub-sample of EPO patents in REGPAT

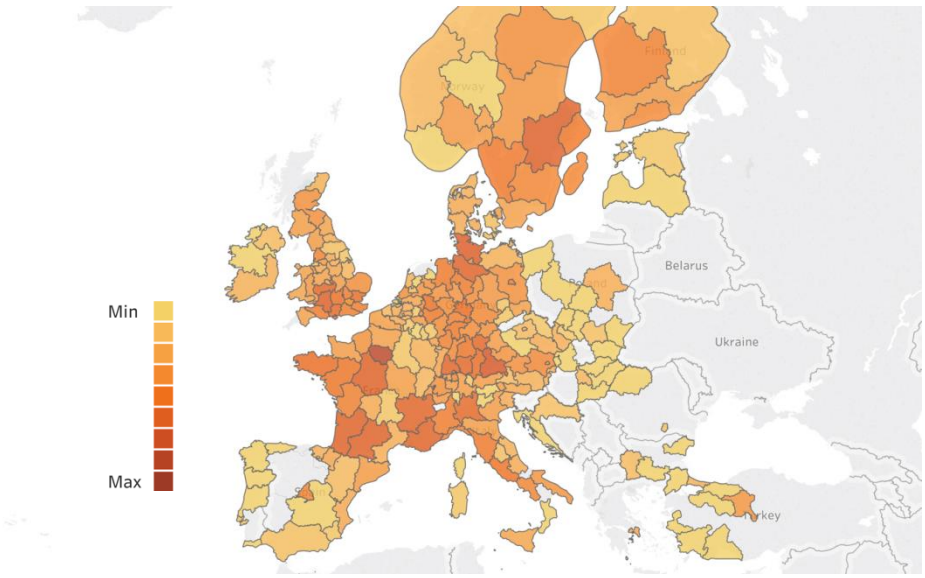


Figure 14: Map of inventor regions (NUTS2) in the USA for the sub-sample of EPO patents in REGPAT

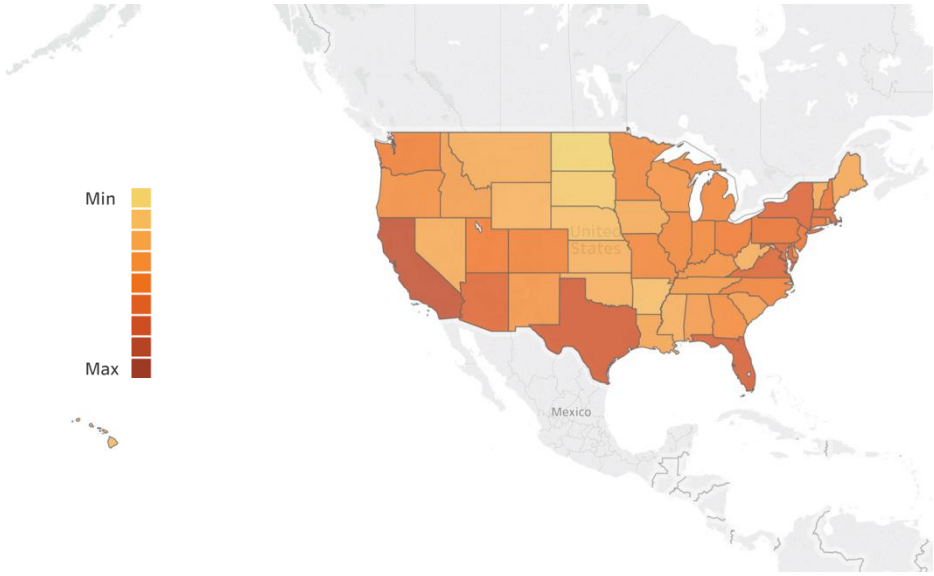


Table 10 shows the evolution of the top 20 source regions for defence innovations. All of them are either located in Europe or in the USA. The joint share in the dataset is 59% in the first interval and 65% in the second, suggesting an increased concentration of the activities.

Table 10: Top 20 regions (NUTS2) of inventor residence in 2002-07 and in 2008-12
(Data from EPO patents in OECD REGPAT)

Rk.	2002 – 2007				2008 – 2012				Change in perc.
	Inventors' region	Ctry	Fam.	Perc.	Inventors' region	Ctry	Fam.	Perc.	
1	ÎLE DE FRANCE	FR	941	11.5%	ÎLE DE FRANCE	FR	820	10.9%	-0,6%
2	CALIFORNIA	US	851	10.4%	CALIFORNIA	US	579	7.7%	-2,7%
3	FLORIDA	US	401	4.9%	TEXAS	US	420	7.7%	0,7%
4	TEXAS	US	397	4.9%	OBERBAYERN	DE	353	5.6%	2,8%
5	VIRGINIA	US	252	3.1%	FLORIDA	US	209	4.7%	-2,1%
6	NEW YORK	US	243	3.0%	MIDI-PYRÉNÉES	FR	208	2.8%	1,6%
7	MARYLAND	US	230	2.8%	SCHLESWIG-HOLSTEIN	DE	182	2.8%	0,4%
8	MASSACHUSETTS	US	225	2.8%	ARIZONA	US	182	2.4%	0,1%
9	ARIZONA	US	187	2.3%	AQUITAINE	FR	180	2.4%	1,0%
10	CENTRE	FR	183	2.2%	GLOUCESTERSH., WILTSH., BRISTOL-BATH	UK	168	2.4%	0,4%
11	ÖSTRA MELLANSVERIGE	SE	178	2.2%	NEW YORK	US	167	2.2%	-0,8%
12	SCHLESWIG-HOLSTEIN	DE	164	2.0%	MASSACHUSETTS	US	157	2.2%	-0,7%
13	FREIBURG	DE	163	2.0%	RHÔNE-ALPES	FR	151	2.1%	0,9%
14	HEREFORDSH., WORCESTERSH., WARWICKSH.	UK	163	2.0%	PROVENCE-ALPES-CÔTE D'AZUR	FR	149	2.0%	0,7%
15	OBERBAYERN	DE	156	1.9%	ÖSTRA MELLANSVERIGE	SE	144	2.0%	-0,3%
16	LÜNEBURG	DE	151	1.8%	VIRGINIA	US	137	1.9%	-1,3%
17	GLOUCESTERSH., WILTSH., BRISTOL-BATH	UK	151	1.8%	CENTRE	FR	123	1.8%	-0,6%
18	CONNECTICUT	US	125	1.5%	LÜNEBURG	DE	121	1.6%	-0,2%
19	AQUITAINE	FR	117	1.4%	TÜBINGEN	DE	120	1.6%	0,5%
20	HAMPSHIRE, ISLE OF WIGHT	UK	115	1.4%	LOMBARDY	IT	120	1.6%	0,7%
	OTHERS		4,824	59.0%	OTHERS		4,888	64.8%	5,8%

3.3 Technological clusters in defence innovation

Defence innovation in terms of the technological clusters defined from the IPC codes associated to the identified patents is described in this section.

Two different approaches are used for the analysis: the first relies on the WIPO concordance table and maps all of the identified inventions in the technological space; the second method focuses on traditional defence sectors (i.e. weapons and transport/vehicles) and on KETs. Paragraph 2.4 in the methodological section provides details of the agreement between IPC codes and technological fields.

The WIPO concordance table was used to classify each invention in the technological space. The descriptive statistics on the distribution of defence innovations patented across technological fields are shown in Table 11.

"Other special machines" represents the largest group of defence patent families (43%); this includes "Weapons and ammunition" (i.e. IPC codes F41 and F42). Other relevant fields are "Measurement" (15.2%), "Transport" (12.3%), "Computer technology" (9.1%), and "Telecommunications" (8.5%).

If inventions associated to weapons and ammunition are excluded, the largest macro area is "Electrical Engineering" (28.5%) which mainly contains ICT related patent families.

Table 11: Distribution of patent families in the defence innovation database identified according to the WIPO concordance table

Sector	Field description	Patent Families	Perc on tot
Electrical engineering	Electrical machinery, apparatus, energy	3228	5.1%
	Audio-visual technology	2767	4.3%
	Telecommunications	5387	8.5%
	Digital communication	2740	4.3%
	Basic communication processes	1443	2.3%
	Computer technology	5779	9.1%
	IT methods for management	495	0.8%
	Semiconductors	1573	2.5%
Instruments	Optics	3232	5.1%
	Measurement	9674	15.2%
	Analysis of biological materials	385	0.6%
	Control	3209	5.0%
	Medical technology	757	1.2%
Chemistry	Organic fine chemistry	422	0.7%
	Biotechnology	476	0.7%
	Pharmaceuticals	375	0.6%
	Macromolecular chemistry, polymers	415	0.7%
	Food chemistry	46	0.1%
	Basic materials chemistry	1508	2.4%
	Materials, metallurgy	1087	1.7%
	Surface technology, coating	2051	3.2%
	Micro-structural and nano-technology	365	0.6%
	Chemical engineering	1214	1.9%
	Environmental technology	892	1.4%
Mechanical engineering	Handling	1250	2.0%
	Machine tools	2061	3.2%
	Engines, pumps, turbines	1530	2.4%
	Textile and paper machines	770	1.2%
	Other special machines (incl. Weapon and Ammunition)	27390	43.0%
	Thermal processes and apparatus	659	1.0%
	Mechanical elements	1799	2.8%
	Transport	7849	12.3%
Other fields	Furniture, games	443	0.7%
	Other consumer goods	1848	2.9%
	Civil engineering	2620	4.1%

"Other special machines" is the largest technological area, but its relative share is decreasing (Figure 15). On the other hand, "Transport" and "Computer technology" are increasing.

Figure 16, Figure 17 and Figure 18 show the trend of defence innovations considering the year 2002 as reference (100%), respectively for the four largest WIPO clusters (excluding Weapons and ammunition), and for a selection of other relevant fields with increasing and decreasing trends.

Figure 15: Relative share of defence patent families by WIPO clusters and priority year
(A single invention belonging to more than one field is counted twice)

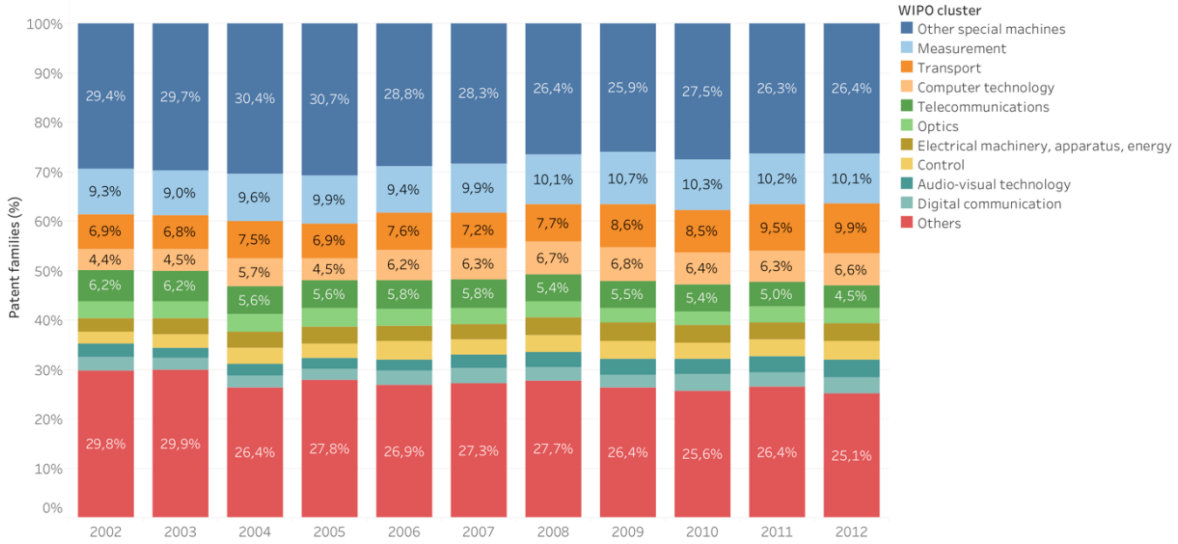
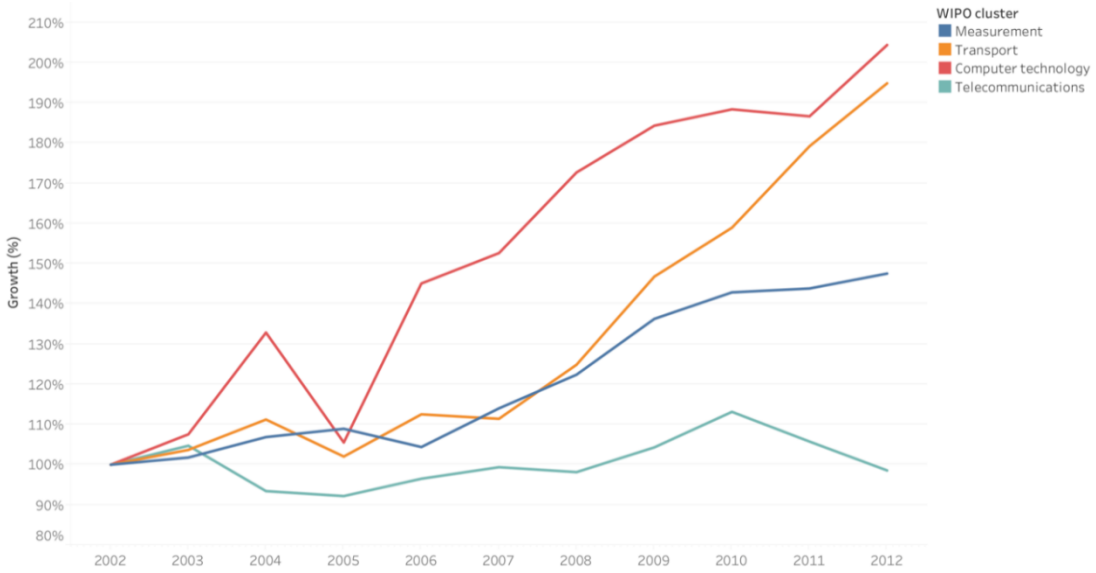


Figure 16: Trend of the four largest WIPO clusters (excluding Weapons and ammunition)
(With 2002 as reference year)



With the aim to further analyse the technological distribution of defence innovations, we applied a second clustering approach that distinguishes 11 fields. These range from traditional fields such as "Weapon and Ammunition" and transportation, to a selection of the most relevant KETs in terms of patents filed. Table 12 reports the number of inventions and the relative share in the dataset.

This clusterisation process does not associate 38.7% of the defence inventions to any of the proposed clusters. In other words, it covers less than two thirds of the database. As expected, the group "Weapons and ammunition" is the largest (41.6%). Interestingly, inventions that are directly associated with transportation are not particularly represented in the database (each not exceeding 5%).

Figure 17: Selection of large WIPO clusters with an increasing trend in time

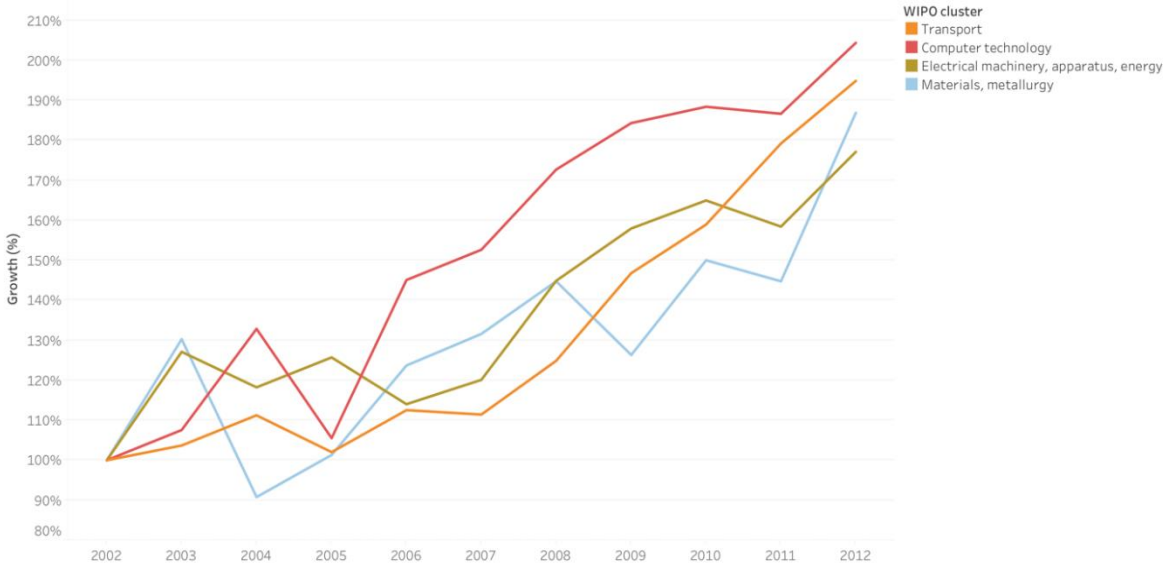


Figure 18: Selection of large WIPO clusters with a decreasing trend in time

Table 12: Distribution of patent families identified in the defence innovation database

(By selected technological fields)

Cluster	Families	Perc. in sample
Weapons and ammunition	26,499	41.6%
Transport/vehicles: aircraft and aeronautics	3,164	5.0%
Transport/vehicles: ships	2,561	4.0%
Transport/vehicles: railways, land vehicles, and others	2,011	3.2%
Aerospace	688	1.1%
Nanotechnology	295	0.5%
Photonics	2,931	4.6%
Biotechnology	330	0.5%
Advanced materials	1,875	2.9%
Micro and nano-electronics	1,997	3.1%
Advanced manufacturing technologies	2,114	3.3%
Cyphering, e-payment	1,179	1.9%
Not included in any of the above clusters	24,641	38.7%

3.4 Main world players

The analysis of innovators in defence related technologies started from approximately 45,000 different names identified in the data source. Although the assignee name is considered to be standardized by the data provider, further processing was carried out to consolidate names more accurately, especially for the largest patent owners and the national entities. A combination of automated clusterisation algorithms and the manual check exploiting the tool OpenRefine (http://openrefine.org/) was used. The process reduced the number of different entities by 5%.

Table 13 shows the 20 largest owners of defence innovations. The list includes large corporations, conglomerates, and governmental bodies[19]. The first 8 portfolio owners (all with more than 1,000 inventions each) show a cumulative share equal to 31.7% of the whole sample. The top 20 innovators represent more than 42% of the sample and the first 40 entities own half of the total defence innovations.

Table 14 shows the relative share of defence inventions for the first 20 assignees[20] in the two time frames considered (2002/07 and 2008/2012). The aim is to highlight potential changes in the defence innovation ecosystem.

The largest growth concerns the Agency for Defence Development (ADD), the South Korean national agency for research and development in defence technology. The largest decreases among the top 20 innovators, in terms of defence inventions, instead regard the combined share of the US governmental agencies and Northrop Grumman.

[19] The appendix contains additional tables where assignees are listed with a lower degree of aggregation and consolidation, e.g. US governmental agencies are not consolidated under a single entity ("US GOVT.") but are shown distinctively ("US ARMY", "US NAVY", etc.); relevant subsidiaries are not collapsed onto the parent company, e.g. SAGEM DEFENCE AND SEC. is not included in SAFRAN; the FINMECCANICA – LEONARDO group is not included in the top 20 as its subsidiaries are considered one by one.

[20] Appendix Table 31 reports the top 20 entities with a lower level of consolidation in the corporate tree of the assignees.

Table 13: Top 20 innovators by number of patent families in the identified sample (2002-12)

Rank	Assignee name	Country	Count of families	Perc.	Cumul.
1	US GOVT	US	4,893	7.7%	7.7%
2	THALES	FR	3,197	5.0%	12.7%
3	RAYTHEON CO	US	3,118	4.9%	17.6%
4	LOCKHEED CORP	US	2,772	4.4%	21.9%
5	BAE	UK	1,872	2.9%	24.9%
6	KOREA REPUBLIC OF GOVT	KR	1,803	2.8%	27.7%
7	HARRIS CORP	US	1,312	2.1%	29.8%
8	NORTHROP GRUMMAN	US	1,238	1.9%	31.7%
9	AIRBUS	EU	821	1.3%	33.0%
10	QINETIQ LTD	UK	671	1.1%	34.1%
11	LEONARDO (FINMECCANICA)	IT	664	1.0%	35.1%
12	RHEINMETALL	DE	663	1.0%	36.1%
13	SAMSUNG THALES CO LTD	KR	651	1.0%	37.2%
14	KOREA AEROSPACE IND LTD	KR	625	1.0%	38.1%
15	LIG NEX1 CO LTD	KR	622	1.0%	39.1%
16	L3 TECHNOLOGIES	US	486	0.8%	39.9%
17	SAAB	SE	486	0.8%	40.6%
18	SAFRAN	FR	474	0.7%	41.4%
19	DIEHL BGT DEFENCE GMBH & CO	DE	406	0.6%	42.0%
20	TEXTRON	US	369	0.6%	42.6%

For the purpose of identifying the innovation output directly owned by governments, national agencies and departments, the standardization of the applicants' names relating to the largest governmental entities in Europe, US, Japan, Canada, India, Australia, and the Republic of Korea was refined[21].

[21] Please note that a partial text-based standardization of Russian applicants was performed. However, due to spelling, transliteration, and translation issues, it was not possible to accurately ascertain whether the Russian applicants are private companies or state-owned institutions. Further research could focus on this specific task.

Table 14: Top 20 patent owners by number of inventions in 2002-07 (left), and in 2008-12 (right)

(The last column reports the change in the relative share between the first and the second period)

Rk.	2002 – 2007			2008 – 2012			Change in perc.
	Assignee name	Ctry	Perc.	Assignee name	Ctry	Perc.	
1	US GOVT	US	8.7%	US GOVT	US	5.4%	-3.30%
2	LOCKHEED CORP	US	4.9%	RAYTHEON CO	US	4.6%	**0.42%**
3	THALES	FR	4.4%	THALES	FR	4.6%	**0.13%**
4	RAYTHEON CO	US	4.2%	REPUBLIC OF KOREA GOVT	KR	3.3%	**2.27%**
5	NORTHROP GRUMMAN	US	3.0%	LOCKHEED CORP	US	3.3%	-1.56%
6	BAE	UK	2.5%	BAE	UK	2.8%	**0.29%**
7	HARRIS CORP	US	2.3%	AIRBUS	EU	1.4%	**0.80%**
8	QINETIQ LTD	UK	1.4%	LIG NEX1 CO LTD	KR	1.4%	**1.19%**
9	REPUBLIC OF KOREA GOVT	KR	1.1%	HARRIS CORP	US	1.3%	-0.99%
10	KOREA AEROSPACE IND LTD	KR	1.0%	LEONARDO (FINMECCANICA)	IT	1.1%	**0.40%**
11	RHEINMETALL	DE	1.0%	SAMSUNG THALES CO LTD	KR	1.1%	**0.43%**
12	L3 TECHNOLOGIES	US	0.9%	RHEINMETALL	DE	0.9%	-0.08%
13	SAAB	SE	0.9%	NORTHROP GRUMMAN	US	0.7%	-2.25%
14	LEONARDO (FINMECCANICA)	IT	0.7%	SAFRAN	FR	0.6%	-0.06%
15	DIEHL BGT DEFENCE GMBH & CO	DE	0.7%	QINETIQ LTD	UK	0.6%	-0.81%
16	GUP KB PRIBOROSTROENIJA	RU	0.7%	KOREA AEROSPACE IND LTD	KR	0.6%	-0.43%
17	SAFRAN	FR	0.7%	SAAB	SE	0.5%	-0.36%
18	SAMSUNG THALES CO LTD	KR	0.7%	L3 TECHNOLOGIES	US	0.5%	-0.40%
19	RAFAEL ADVANCED DEFENCE SYS	IL	0.6%	GUP KB PRIBOROSTROENIJA	RU	0.5%	-0.21%
20	AIRBUS	EU	0.6%	NEXTER	FR	0.5%	**0.02%**

Table 15: Largest governmental innovators (e.g. aggregation of national agencies, defence departments)

(By number of patent families in the identified sample for 2002-12)

Rank	Assignee name Government Agencies of:	Count of families	Perc.	Cumul.
1	US GOVT.	4,893	7.7%	7.7%
6	REPUBLIC OF SOUTH KOREA GOVT.	1,803	2.8%	27.7%
28	UK GOVT.	243	0.4%	46.2%
35	JAPAN GOVT.	194	0.3%	48.6%
55	CANADA GOVT.	115	0.2%	53.5%
65	FRANCE GOVT.	86	0.1%	55.0%
68	INDIA GOVT.	75	0.1%	55.4%

The results of this further standardization procedure show a significant combined portfolio for the US agencies (Table 15) although decreasing in terms of relative share in the two time frames (Table 16). Government owned research output increased in terms of the relative share for South Korea, Japan, and India.

Table 16: Largest governmental innovators (aggregation of national agencies, defence departments, etc.)
(By number of patent families in the two time frames, 2002-07 and 2008-12)

2002 – 2007			2008 – 2012			Change in perc.
Rk.	Assignee name	Perc.	Rk.	Assignee name	Perc.	
1	US GOVT.	8.7%	1	US GOVT.	5.4%	-3.30%
9	REPUBLIC OF SOUTH KOREA GOVT.	1.1%	4	REPUBLIC OF KOREA GOVT.	3.3%	**2.27%**
28	UK GOVT.	0.4%	31	JAPAN GOVT.	0.3%	**0.01%**
37	JAPAN GOVT.	0.3%	40	UK GOVT.	0.2%	-0.21%
46	CANADA GOVT.	0.2%	68	INDIA GOVT.	0.1%	**0.06%**
57	FRANCE GOVT.	0.1%	72	FRANCE GOVT.	0.1%	-0.06%
162	INDIA GOVT.	0.05%	79	CANADA GOVT.	0.1%	-0.14%

3.5 Dual use technologies: main findings

The results of the analyses on the dual use defence innovations, identified according to our methodology relying on citations, are reported in this section. The definition of dual use innovations employed in this study distinguishes between two types: the first based on forward citations and the second on backward citations as explained in the methodological section. In this section, the analysis focuses on the type-1 definition of dual use, that is, when a defence innovation has at least one subsequent civilian application. Section 3.6 investigates the knowledge base of defence innovations using the type-2 definition of dual use, that is to say, when the defence innovations are developed from a knowledge base composed of civilian innovations.

Concerning the "defence to civilian" application direction, Table 17 shows the statistics for the whole period considered (2002-2012) and for the sub-samples based on the selection criteria used to build the database. It is worth remembering that the definition employed here identifies a dual use patent family when it has at least one forward citation that is not included in the defence innovation database and does not belong to any of the companies listed in the SIPRI database[22].

The presence of dual use technologies is not marginal at all. These technologies represent about 41% of the defence patents filed between 2002 and 2012. It is worth remembering that the data examined - patent repositories - represent only a fraction of the defence innovations, the disclosed ones, those that are likely to have potential outside the boundaries of the defence and security sector. The share differs with respect to the selection criteria: *(i)* the "firm" selection subsample shows the highest proportion of dual use inventions (50%); *(ii)* the subsamples based on the "IPC" and "keyword criteria show similar shares of dual use inventions (about 28%). It is worth noting that the entry criterion based on keywords only may identify patents that are neither developed by military firms nor in technological fields strictly characterized by defence IPC codes: such innovations may be civil inventions that mention potential military applications so they could be dual in nature.

The values reported in column (3) indicate that if a defence innovation receives at least one citation, then it does so as non-defence in 60% of cases the citation(s) from a subsequent patent classified. In other words, if we restrict the analysis to the cited patents, the share of dual-use technologies rises from 41% to 61%.

[22] As a further indicator, a less strict definition was also used which identifies dual use patent families when they have at least one forward citation that is not included in the defence innovation database (it considers citations from companies with less than 50% of revenues from arms sales as civilian follow-ups). This definition leads to similar figures to those shown in the table, with a small increase in the identification of dual use inventions (+2%).

Table 17: Proportion of dual use innovations according to the Type 1 definition
(At least one forward citation comes from a civilian invention)

Dual use: TYPE 1 Reference sample	(1) Patent Families	(2) Cited Families	(3) Perc. of (1)	(4) Dual Use Fam.	(5) Perc. on (1)
Full sample (2002-12)	63,714 (100%)	38,795	61%	26,211	41%
Subsample from:					
"firm" criterion	34,137 (54%)	21,996	64%	16,901	50%
"IPC" criterion	32,025 (50%)	18,680	58%	8,958	28%
"keyword" criterion	15,452 (24%)	8,665	56%	4,310	28%

Table 18 reports some example of defence patents identified by applying the proposed method with at least one forward citation that is associated to a subsequent civilian application.

Table 18: Examples of dual use patent

Defence patent Dual use	Title		Fwd. Cit. Civilian application	Title
US8590201B2	Firearm grip	→	US9073200B2	Pliant removable airbrush grip
EP2395314A2	Blast and/or ballistic resistant member	→	EP2951222B1	Low free mdi pre-polymers for rotational casting
US9206941B2	Apparatus and method for clamping	→	US9696610B2	Chain link fence attachment clip
		→	US9767776B2	Support stand for a musical instrument

3.5.1 Trend

When looking at the trends of the proportion of dual use patents on military ones, it should be kept in mind that the employed method relies on the presence of at least one civil forward citation. Due to the dynamics of the citing process, the number of cited families decreases in time since older families are more likely to receive forward citations. Hence, by definition, recent innovations are less likely to be cited and to be identified as dual.

The percentage of dual use inventions shows a decreasing trend (Figure 19), which can only be partially explained by the citation dynamics. In fact, the trend also appears decreasing when the share of dual use inventions is calculated as conditional to having at least one forward citation (Figure 20). Such evidence suggests that the reduction of dual use cases is not only induced by the identification method. However, the result calls for further studies to investigate the citation dynamics further and explore whether a forward civilian citation (that qualifies the invention as a dual use one) requires a longer time than a defence citation.

Figure 19: Percentage of dual use innovations out of the number of total defence inventions

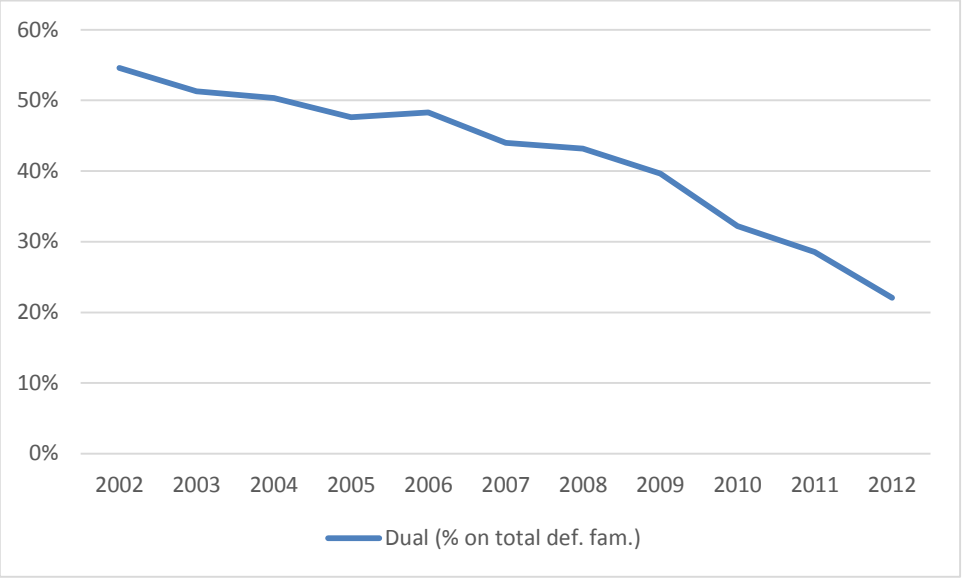
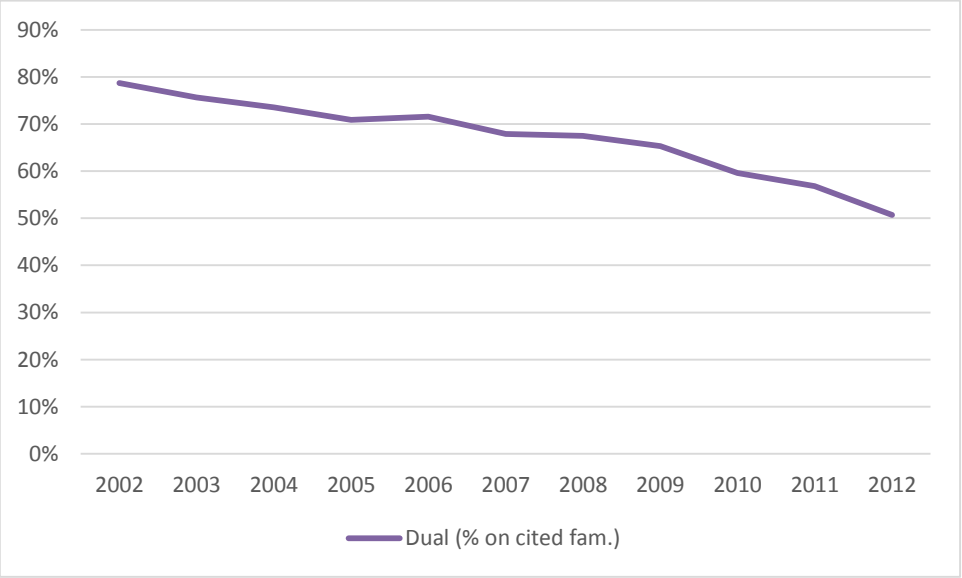


Figure 20: Percentage of dual use innovations out of the number of cited families



3.5.2 Geography

Table 19 reports the distribution of defence patents and dual use technologies across the different priority patent offices considered in the analysis. Patent offices (POs), a proxy for the source country of innovations, are ordered by the number of dual use inventions. The largest PO is the USPTO with more than 18 thousand patent families, representing about 69% of the total dual use inventions identified in the sample. The second PO is that of France with less than one tenth of dual use families (6.5%) compared to the USPTO.

Due to the differences in the amount of defence inventive output from each country, it is interesting to compare the relative share of dual use cases compared to the global average (41.1%). Among the first 10 POs the two extremes in terms of share of dual

use patents are the USPTO and the Russian Federation. The former drives the global average value up with 63.9% of its defence innovations finding a subsequent civilian application. Among the largest portfolios, the Russian Federation office shows a low proportion of dual use inventions (4.9%).

Table 19: Top 10 priority offices by number of dual use families

Priority office	Number of **defence fam.** (%)	**Number of dual use fam.** (%)	**Perc. of dual use fam. on Office defence fam.**
USA	28,347 (44.5%)	18,107 (69.1%)	63.9%
FRANCE	5,283 (8.3%)	1,715 (6.5%)	32.5%
SOUTH KOREA, REPUBLIC OF	7,053 (11.1%)	1,483 (5.7%)	21.0%
GERMANY	4,368 (6.9%)	1,051 (4.0%)	24.1%
UK	2,573 (4.0%)	915 (3.5%)	35.6%
JAPAN	2,862 (4.5%)	810 (3.1%)	28.3%
EPO	1,348 (2.1%)	610 (2.3%)	45.3%
RUSSIAN FED.	6,147 (9.6%)	304 (1.2%)	4.9%
ISRAEL	893 (1.4%)	276 (1.1%)	30.9%
PCT - WIPO	714 (1.1%)	232 (0.9%)	32.5%
Others	4,126 (6.5%)	705 (2.7%)	17.1%
Total	**63,714 (100%)**	**26,208 (100%)**	**41.1%**

The POs with at least 50 defence inventions during the 2002-12 period can be classified according to the proportion of dual use patent families:

- Higher than the global average: USPTO (64%); Taiwan (46%); EPO and Australia (45%).
- Between 25 and 40%: China (39%); UK (36%); France and the Netherlands (33%); Israel (31%); Japan (28%).
- Between 10 and 25%: Germany and Norway (24%); South Africa and Sweden (22%); Switzerland (23%); Italy, Austria and the Republic of South Korea (21%); Canada (20%); Finland (15%); India (13%).
- Below 10%: Spain (8%); Greece (7%); Russian Federation (5%); Bulgaria and Czech Republic (4%); Turkey (3%); Romania (1%); Poland (0.4%); Slovakia (less than 0.1%).

The analysis of the EPO patents, as reported in the OECD REGPAT, allows dual use technologies to be geo-localized at the level of regions (NUTS2) Figure 21 and Figure 22. Table 20 shows the first 20 regions by the number of dual use inventions, and the share of dual use inventions in the total regional portfolio of defence patents for each region is also reported.

Table 20: Share of dual use by inventor regions (NUTS2) for the sub-sample of EPO patents

Rank	Inventor region	Country	Families	Dual use (%)
1	ÎLE DE FRANCE	FR	1,761	43.2%
2	CALIFORNIA	US	1,430	72.1%
3	TEXAS	US	817	61.3%
4	FLORIDA	US	610	84.4%
5	OBERBAYERN	DE	509	21.8%
6	NEW YORK	US	410	82.2%
7	VIRGINIA	US	389	67.1%
8	MASSACHUSETTS	US	382	72.0%
9	ARIZONA	US	369	56.6%
10	SCHLESWIG-HOLSTEIN	DE	346	29.5%
11	MARYLAND	US	344	73.0%
12	ÖSTRA MELLANSVERIGE	SE	322	41.0%
13	GLOUCESTERSHIRE, WILTSHIRE AND BRISTOL-BATH	UK	319	49.8%
14	CENTRE	FR	306	24.8%
15	MIDI-PYRÉNÉES	FR	299	42.1%
16	AQUITAINE	FR	297	44.1%
17	LÜNEBURG	DE	272	26.1%
18	FREIBURG	DE	262	27.9%
19	PROVENCE-ALPES-CÔTE D'AZUR	FR	255	38.8%
20	RHÔNE-ALPES	FR	243	49.4%
	OTHERS		9,853	49.3%

Figure 21: Map of dual use by inventor region (NUTS2) in Europe (regions with at least 10 patent families) for the sub-sample of EPO patents

(Range from minimum to maximum share of dual use inventions out of total defence innovations)

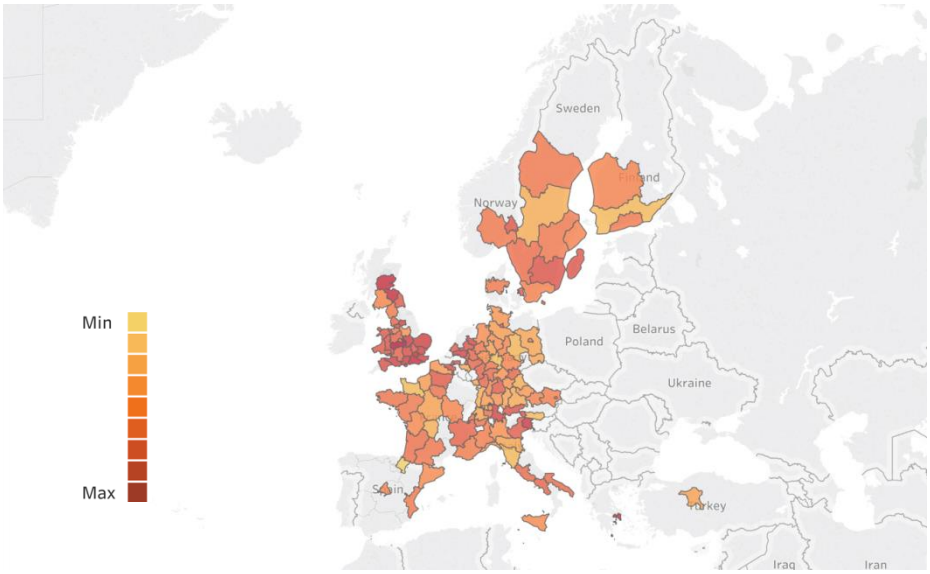
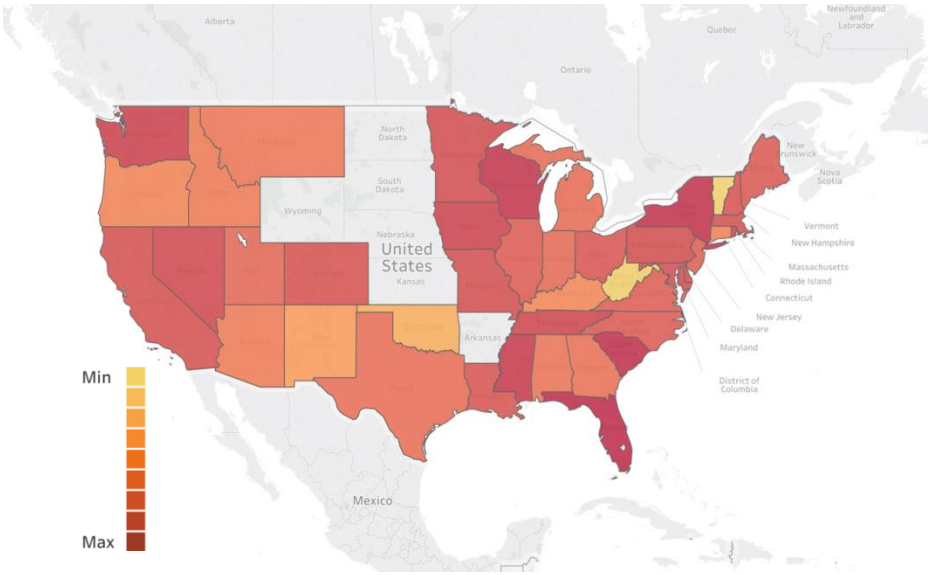


Figure 22: Map of dual use by inventor region (NUTS2) in the US (regions with at least 10 patent families) for the sub-sample of EPO patents

(Range from minimum to maximum share of dual use inventions out of total defence innovations)



Technological clusters

Table 21 shows the share of dual use innovations in each technological cluster identified according to the WIPO concordance table.

Only three technological fields are below the sample average. "Other special machines (incl. Weapons and Ammunition)" is the largest field in the defence innovation database (43.0%), but it also shows the lowest share of dual use cases (25.5%). In this field, defence patents show a relatively low probability of having a subsequent civilian application similar to the findings reported in Acosta et al. 2013. The proportion of defence patents related to "Food chemistry" is particularly low (0.1%), these applications also show a relatively low share of dual use cases (34.8%). Similarly, "Basic materials chemistry" also seems to play a marginal role in defence innovations (2.4%) and to have a relatively low proportion of dual use cases (35.5%).

All of the other fields show above average proportion of dual use inventions. In general, fields related to "Electrical engineering" show the highest shares of dual use inventions (between 56.6% and 64.1%). The field with the highest proportion of dual use applications is "Medical Technology" in which 2 out of 3 patents find a subsequent civil application.

The section 6.4 of the Appendix reports a collection of figures detailing trends, geo-localization, and main assignees of dual use innovations for a selection of technological fields.

Table 21: Presence of dual use inventions across WIPO technological clusters.
"H/L" indicates whether the share is higher or lower than the full sample value (41.1%)

Sector	Field description	Defence families	Dual use fam.	Dual use fam. (% on tot. field)	H/L
	Full sample	**63,714**	**26,208**	**41.1%**	
Electrical engineering	Electrical machinery, apparatus, energ	3,228	1,828	56.6%	↑
	Audio-visual technology	2,767	1,576	57.0%	↑
	Telecommunications	5,387	3,306	61.4%	↑
	Digital communication	2,740	1,594	58.2%	↑
	Basic communication processes	1,443	875	60.6%	↑
	Computer technology	5,779	3,630	62.8%	↑
	IT methods for management	495	294	59.4%	↑
	Semiconductors	1,573	1,009	64.1%	↑
Instruments	Optics	3,232	1,749	54.1%	↑
	Measurement	9,674	5,275	54.5%	↑
	Analysis of biological materials	385	200	51.9%	↑
	Control	3,209	1,835	57.2%	↑
	Medical technology	757	504	66.6%	↑
Chemistry	Organic fine chemistry	422	191	45.3%	↑
	Biotechnology	476	239	50.2%	↑
	Pharmaceuticals	375	161	42.9%	↑
	Macromolecular chemistry, polymers	415	216	52.0%	↑
	Food chemistry	46	16	34.8%	↓
	Basic materials chemistry	1,508	536	35.5%	↓
	Materials, metallurgy	1,087	542	49.9%	↑
	Surface technology, coating	2,051	1,150	56.1%	↑
	Micro-structural and nano-technology	365	212	58.1%	↑
	Chemical engineering	1,214	658	54.2%	↑
	Environmental technology	892	468	52.5%	↑
Mechanical engineering	Handling	1,250	680	54.4%	↑
	Machine tools	2,061	973	47.2%	↑
	Engines, pumps, turbines	1,530	719	47.0%	↑
	Textile and paper machines	770	424	55.1%	↑
	Other special machines (incl. Weapons and Ammunition)	27,390	6,983	25.5%	↓
	Thermal processes and apparatus	659	377	57.2%	↑
	Mechanical elements	1,799	885	49.2%	↑
	Transport	7,849	3,478	44.3%	↑
Other fields	Furniture, games	443	263	59.4%	↑
	Other consumer goods	1,848	1,100	59.5%	↑
	Civil engineering	2,620	1,254	47.9%	↑

3.5.3 Main players and dual use

The main assignees (with at least 200 inventions filed in the time frame) are listed in the following tables (Table 22 to Table 25) according to different criteria: the largest portfolios of defence innovations (Table 22) and the assignees with the highest (Table 23) and lowest shares of dual use families in their portfolio (Table 24) among those. Finally in Table 25 only governmental agencies are shown with the respective share of dual use related patents in their patent portfolio.

Table 22: Top 20 innovators by number of patent families: share of dual use families

Rank	Assignee	Ctry	Fam.	Dual use fam. (#)	Dual use fam. (%)
1	US GOVT	US	4,893	3,130	64.0%
2	THALES	FR	3,197	1,404	43.9%
3	RAYTHEON CO	US	3,118	2,118	67.9%
4	LOCKHEED CORP	US	2,772	2,052	74.0%
5	BAE	UK	1,872	982	52.5%
6	REPUBLIC OF SOUTH KOREA GOVT	KR	1,803	439	24.3%
7	HARRIS CORP	US	1,312	1,104	84.1%
8	NORTHROP GRUMMAN	US	1,238	974	78.7%
9	AIRBUS	EU	821	148	18.0%
10	QINETIQ LTD	UK	671	358	53.4%
11	LEONARDO (FINMECCANICA)	IT	664	275	41.4%
12	RHEINMETALL	DE	663	112	16.9%
13	SAMSUNG THALES CO LTD	KR	651	165	25.3%
14	KOREA AEROSPACE IND LTD	KR	625	153	24.5%
15	LIG NEX1 CO LTD	KR	622	130	20.9%
16	L3 TECHNOLOGIES	US	486	360	74.1%
17	SAAB	SE	486	238	49.0%
18	SAFRAN	FR	474	138	29.1%
19	DIEHL BGT DEFENCE GMBH & CO	DE	406	104	25.6%
20	TEXTRON	US	369	163	44.2%

Table 23: Top 10 innovators by share of dual use families in their portfolio
(Among the assignees with at least 200 inventions filed in the time frame)

Rank	Assignee	Ctry	Fam.	Dual use fam. (#)	Dual use fam. (%)
1	HARRIS CORP	US	1,312	1104	84.1%
2	NORTHROP GRUMMAN	US	1,238	974	78.7%
3	GEN DYNAMICS CORP	US	237	177	74.7%
4	L3 TECHNOLOGIES	US	486	360	74.1%
5	LOCKHEED CORP	US	2,772	2052	74.0%
6	BOEING CO	US	248	171	69.0%
7	RAYTHEON CO	US	3,118	2118	67.9%
8	US GOVT	US	4,893	3130	64.0%
9	ALLIANT TECHSYSTEMS INC	US	229	146	63.8%
10	UNITED TECHNOLOGIES CORP	US	291	170	58.4%

Table 24: Bottom 10 innovators by share of dual use families in their portfolio
(Among the assignees with at least 200 inventions filed in the time frame)

Rank	Assignee name	Ctry	Fam.	Dual use fam. (#)	Dual use fam. (%)
1	GUP KB PRIBOROSTROENIJA	RU	369	5	1.4%
2	KRAUSS MAFFEI WEGMANN	DE	243	41	16.9%
3	RHEINMETALL	DE	663	112	16.9%
4	NEXTER	FR	526	99	18.8%
5	AIRBUS	EU	821	148	18.0%
6	LIG NEX1 CO LTD	KR	622	130	20.9%
7	MITSUBISHI Group	JP	308	72	23.4%
8	REPUBLIC OF KOREA GOVT	KR	1803	439	24.3%
9	KOREA AEROSPACE IND LTD	KR	625	153	24.5%
10	UK GOVT	UK	243	60	24.7%

Table 25: Governmental agencies and dual use families

Rank	Assignee name	Fam.	Dual use fam. (#)	Dual use fam. (%)
1	US GOVT	4,893	3,130	64.0%
6	REPUBLIC OF SOUTH KOREA GOVT	1,803	439	24.3%
28	UK GOVT	243	60	24.7%
36	JAPAN GOVT	194	85	43.8%
55	CANADA GOVT	115	55	47.8%
65	FRANCE GOVT	86	17	19.8%
68	INDIA GOVT	75	8	10.7%

3.6 Civil knowledge base of defence innovations

With the aim of exploring the knowledge base from which defence innovations stem and to identify dual use cases from civil to defence innovations, the backward citations of military patents in the years 2010-12 were also examined (see the methodological section 2.3.3 for details). The defence patent families having only civil backward citations (among those with priority after 2002) are considered to be dual use cases with a full civil knowledge base.

The analysis shows that 38% of the 19,843 defence inventions identified in the years 2010-12 are based exclusively on previous civil citations (Table 26). Although the finding is limited to a restricted sample and lies outside the main goal of the study, it suggests that the direction of knowledge flow from civil to defence is not negligible and calls for further studies to explore the characteristics of those civil technologies representing a background for subsequent military developments.

Table 26: Proportion of dual use innovations

(All the backward citations of defence inventions are civilian patents)

Reference sample	Patent Families	Dual Use Fam.	Perc.
Restricted sample (2010-12)	19,843 (100%)	7,443	38%
Subsample from:			
"firm" criterion	11,295 (57%)	5,541	49%
"IPC" criterion	9,612 (48%)	2,076	22%
"keyword" criterion	4,709 (24%)	932	20%

3.7 Knowledge spillovers of defence and dual use technologies

Using the citation network built on the patents in the sample, the priority offices of the cited and citing patent families were analysed. The comparison of cited and citing priority offices provides a proxy for the origin of (subsequent) inventions. The analysis led to the construction of a matrix of flows across patent offices/countries. Each flow represents the knowledge spillover from a source geographical area to a subsequent implementation. In particular, this approach is useful in estimating the size of domestic spillovers compared to cross-border ones.

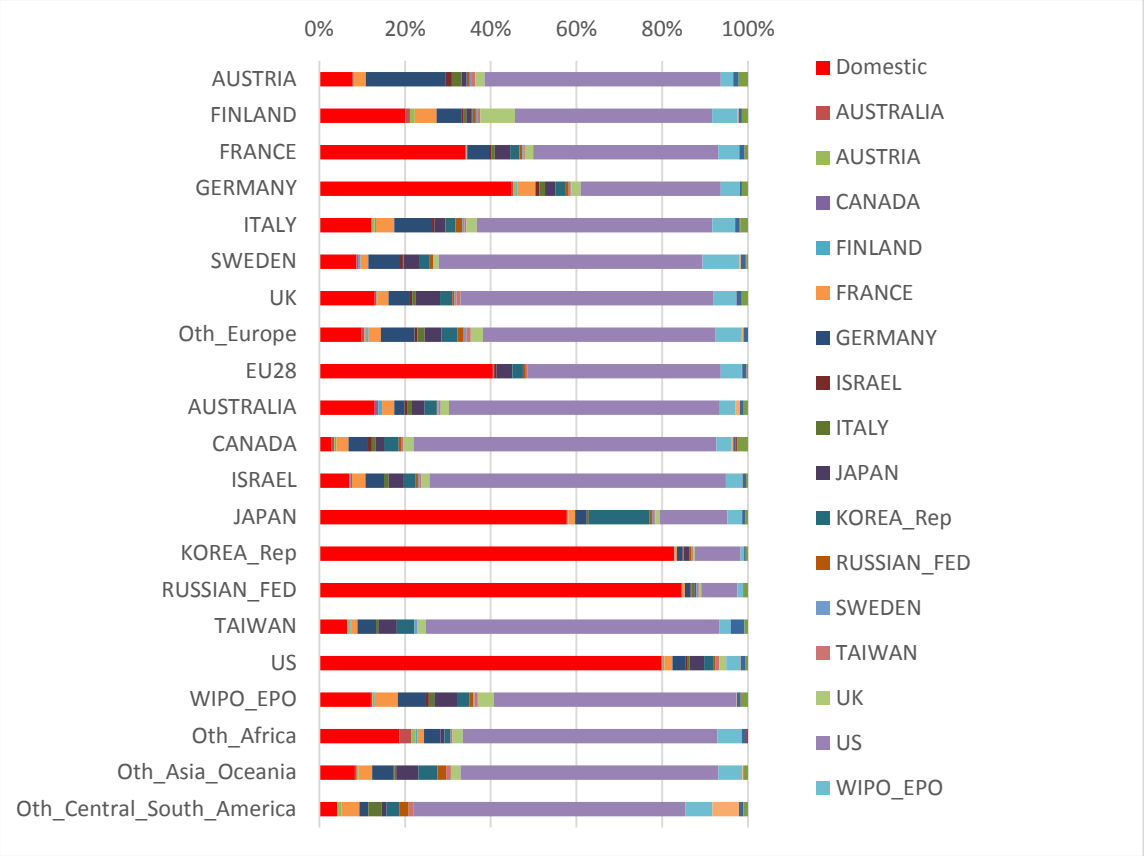
Figure 23 describes the citation flows for the most relevant POs. Results show a marked heterogeneity across countries in the geographical localization of the knowledge base for defence innovations. The domestic knowledge in some countries is the largest knowledge base for subsequent technical developments (e.g. the USA, South Korea, or the Russian Federation). On the contrary, the defence innovations developed in countries like Australia, Canada, or Italy constitute the knowledge base for subsequent inventions that are invented elsewhere, in most cases in the USA. By way of example, Swedish defence innovations are cited by inventions originated in Sweden in 9% of cases and in the USA in 80% of cases.

Innovations developed in Europe (EU28) are mainly the base for other defence inventions developed in the same area (40%) or in the USA (45%). Among the rest of the world, Asian countries are the main areas exploiting the European knowledge base.

Please note that the analysis at this stage does not control for the overall propensity of receiving citations. There might be differences between the patent examiners of diverse regions in the propensity to add domestic citations rather than screening the prior art globally. Language barriers and access to shared patenting procedures might favour citation flows across certain areas (e.g. US globally, German citations to Austrian patents, etc.) and limit the international scope of citations in some other areas (e.g. the Russian Federation, Asian countries, etc.). Further research should improve the estimates by considering the systemic propensity to domestic citations (considering all filed patents).

Figure 23: Citation flows for the main offices

(Origin country on the left axis; domestic flow in red, citations from other countries in different colours)



The same analysis carried out on the subsample of dual use innovations and civil citations shows some differences. Figure 24 shows the relative relevance of domestic and cross-border flows for the subsample of dual use cases while Table 27 provides a direct comparison of the values for the domestic flows of dual and non-dual cases.

Considering dual use innovations generated in the EU28 area, a relative low share of these innovations is used as a base for developing subsequent European inventions. The within EU28 flows represent about 25% of total citation flows. Follow-up inventions originated in the EU28 area are particularly high in the US. Indeed, about 53% of citations to EU28 dual use patents come from the USA. In contrast, about 76% of dual use patents developed in the USA feed future domestic inventions.

Figure 24: Citation flows of dual use inventions for the main offices

(Origin country on the left axis; domestic flow in red, citations from other countries in different colours)

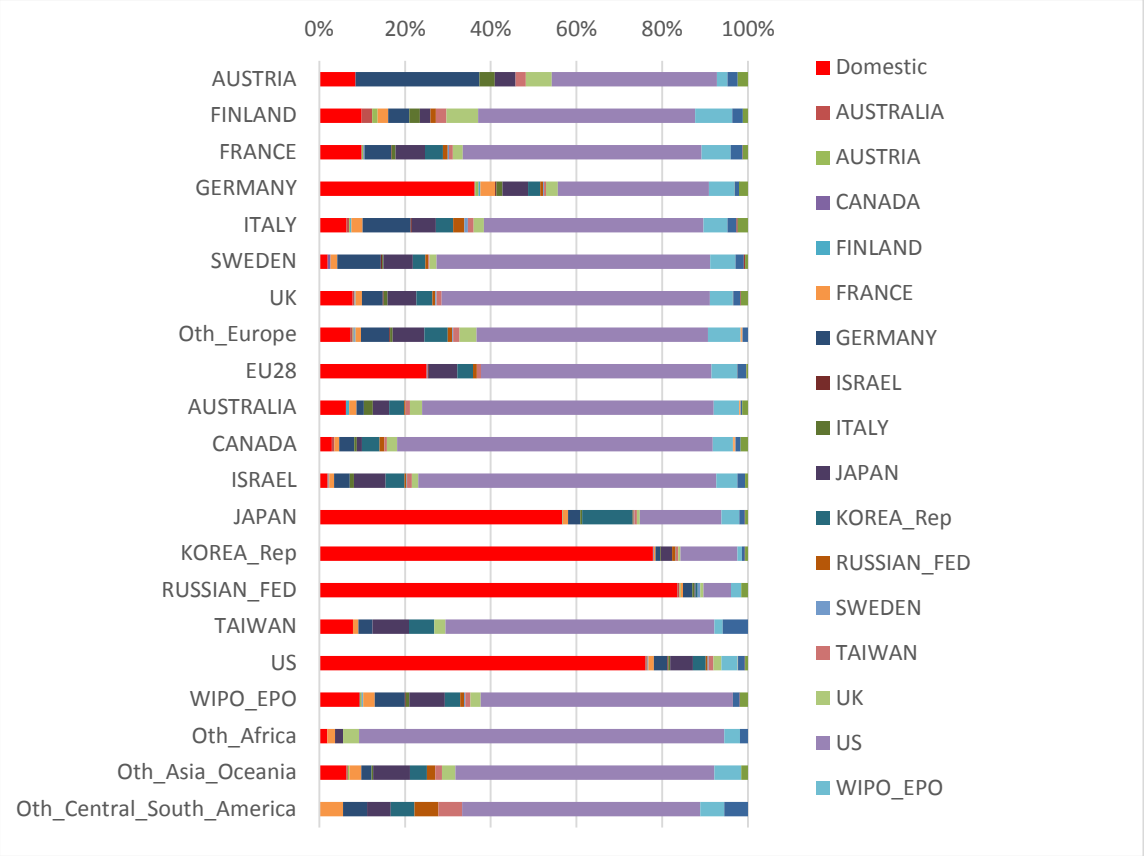


Table 27: Share of domestic knowledge flow compared to cross border for the sub-samples of non-dual and dual use inventions.

Origin Office	Domestic flow (%)		Difference
	Non-dual inventions	Dual use	
Austria	10.9%	8.4%	2.4%
Finland	37.5%	9.9%	27.6%
France	52.6%	9.8%	42.7%
Germany	52.9%	36.2%	16.7%
Italy	17.4%	6.4%	11.0%
Sweden	14.7%	2.0%	12.7%
UK	24.4%	7.8%	16.7%
Other European countries	11.4%	7.2%	4.2%
EU28	56.3%	25.0%	31.3%
Australia	19.4%	6.3%	13.1%
Canada	4.0%	2.9%	1.1%
Israel	12.1%	1.9%	10.2%
Japan	61.2%	56.6%	4.6%
South Korea	88.5%	77.8%	10.8%
Russian Fed.	85.9%	83.5%	2.4%
Taiwan	4.4%	7.8%	-3.4%
USA	85.2%	76.0%	9.1%
WIPO - EPO	16.6%	9.2%	7.4%
Other Africa	30.4%	1.9%	28.5%
Other Asia/Oceania	11.1%	6.3%	4.8%
Other Central/South America	6.1%	0.0%	6.1%
Total, excluding USA	**49.4%**	**23.8%**	**25.6%**
Total	**72.9%**	**66.5%**	**6.4%**

For the purpose of highlighting these differences, the share of domestic flows identified for dual use cases was compared with the share for defence innovations with no subsequent civil application (Table 27). In general, the domestic flow of dual use innovations (66.5% for the total sample) is smaller than that calculated for the non-dual inventions (72.9% for the total sample).

The difference is even more pronounced if the USA is excluded: the average domestic flow of non-dual inventions is 49.4% while it is only 23.8% for dual use ones. The evidence suggests that dual use innovations are more likely to be developed somewhere else rather than the original knowledge base compared to the average defence patent, or in other words, the cross country spillovers for dual innovations seem to be higher than for military patents in general.

4 Conclusion

The study proposes a method that relies on patent data to identify defence innovations and then focuses on those cases that are linked to subsequent applications for civilian use. The latter are meant to capture dual use technologies. Extending previous empirical approaches, diverse search strategies are combined which rely on selected company names (defence firms in the SIPRI database), the use of IPC codes, and the presence of military keywords in patent text fields. The relationships across the patent citation network was exploited to identify civil inventions stemming from defence ones.

The method proposed identified 177,143 patents which correspond to 63,714 patent families in the years 2002-2012. The defence innovation database shows an increasing trend towards patenting inventions which cover a wide range of technological fields. The selected firms are not only active in traditional defence fields (e.g. weapons, ammunition, explosives, and transport vehicles) but also in the area of "Electrical Engineering" which contains ICTs and in the area of Instruments for measurement and control. Moreover, inventions in these non-traditional fields are increasing compared to Weapons and Ammunition.

The largest geographical source of innovations is the USA, but South Korea has been increasing significantly due to the contribution of private firms as well as government agencies and ministries. Focusing on narrower geographical boundaries (NUTS2), the largest twenty regions in terms of defence patents are all in the USA or Europe. These account for around 38% of total defence innovations. A similar proportion can be found when considering the largest twenty portfolio holders: these innovators account for 40% of defence patent families and include national agencies.

The analysis of dual use cases is based on the proposed operationalization: a dual invention was defined whenever a defence innovation finds a subsequent civil application, i.e. a defence patent is cited by at least one non-military invention. The proportion of dual use inventions in the whole dataset is 41%, but the value shows heterogeneity across technological fields and geographical areas. The technological fields of weapons and ammunition appear less often in dual use applications compared to the rest of the technological space. Fields related to "Electrical engineering", together with "Medical Technology", show the highest proportions of dual use inventions.

There are significant differences between the countries of origin of the defence innovations: the USA reports the highest share of dual use cases (63.9%) while the shares for the other countries are below 46% and in some cases close to zero.

The analysis of the patent citation network led to the generation of a matrix of knowledge flows highlighting the presence and strength of knowledge spillovers within

and across countries. The results suggest a significant heterogeneity in the share of domestic knowledge flows from military to civil uses. Significantly, defence innovations generated in the European area are subsequently cited by inventions developed in the USA. Interestingly, the share of innovations originated from previous defence inventions developed in another country is higher when the new one is dual rather than non-dual: this suggests that dual use inventions are more likely to diffuse across national borders.

The present study has limitations which can be addressed in future research. In particular, future studies could improve the identification of dual use cases starting from the proposed method. A possible method to test and refine the identification could rely on the application of semantic analyses on the text fields of the citing patent with the aim of evaluating the presence of false positive civilian applications more accurately. The analyses could provide more accurate results when considering macro level data on the input factors (e.g. national expense in the defence sector) and the characteristics of the patent systems (e.g. language and cooperation treaties facilitating citation flows). Finally, future studies could further explore the dual use phenomenon when the direction is from civil to defence innovations.

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6 Appendix

6.1 Technological fields based on the WIPO concordance table

This clustering method is derived from a full mapping on a mid-level aggregation of IPC codes based on the WIPO concordance table that links the IPC codes to 35 technological fields.

Table 28: WIPO concordance table

Sector	Field	List of IPC codes
Electrical engineering	Electrical machinery, apparatus, energy	F21H, F21K, F21L, F21S, F21V, F21W, F21Y, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H02B, H02G, H02H, H02J, H02K, H02M, H02N, H02P, H02S, H05B, H05C, H05F, H99Z
Electrical engineering	Audio-visual technology	G09F, G09G, G11B, H04N0003, H04N0005, H04N0007, H04N0009, H04N0011, H04N0013, H04N0015, H04N0017, H04N0019, H04N0101, H04R, H04S, H05K
Electrical engineering	Telecommunications	G08C, H01P, H01Q, H04B, H04H, H04J, H04K, H04M, H04N0001, H04Q
Electrical engineering	Digital communication	H04L, H04N0021, H04W
Electrical engineering	Basic communication processes	H03B, H03C, H03D, H03F, H03G, H03H, H03J, H03K, H03L, H03M
Electrical engineering	Computer technology	G06C, G06D, G06E, G06F, G06G, G06J, G06K, G06M, G06N, G06T, G10L, G11C
Electrical engineering	IT methods for management	G06Q
Electrical engineering	Semiconductors	H01L
Instruments	Optics	G02B, G02C, G02F, G03B, G03C, G03D, G03F, G03G, G03H, H01S
Instruments	Measurement	G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N0001, G01N0003, G01N0005, G01N0007, G01N0009, G01N0011, G01N0013, G01N0015, G01N0017, G01N0019, G01N0021, G01N0022, G01N0023, G01N0024, G01N0025, G01N0027, G01N0029, G01N0030, G01N0031, G01N0035, G01N0037, G01P, G01Q, G01R, G01S, G01V, G01W, G04B, G04C, G04D, G04F, G04G, G04R, G12B, G99Z
Instruments	Analysis of biological materials	G01N0033
Instruments	Control	G05B, G05D, G05F, G07B, G07C, G07D, G07F, G07G, G08B, G08G, G09B, G09C, G09D
Instruments	Medical technology	A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N, H05G
Chemistry	Organic fine chemistry	A61K0008, A61Q, C07B, C07C, C07D, C07F, C07H, C07J, C40B
Chemistry	Biotechnology	C07G, C07K, C12M, C12N, C12P, C12Q, C12R, C12S
Chemistry	Pharmaceuticals	A61K0006, A61K0009, A61K0031, A61K0033, A61K0035, A61K0036, A61K0038, A61K0039, A61K0041, A61K0045, A61K0047, A61K0048, A61K0049, A61K0050, A61K0051, A61K0101, A61K0103, A61K0125, A61K0127, A61K0129, A61K0131, A61K0133, A61K0135, A61P
Chemistry	Macromolecular chemistry, polymers	C08B, C08C, C08F, C08G, C08H, C08K, C08L
Chemistry	Food chemistry	A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, C12C, C12F, C12G, C12H, C12J, C13B0010, C13B0020, C13B0030, C13B0035, C13B0040, C13B0050, C13B0099, C13D, C13F, C13J, C13K
Chemistry	Basic materials chemistry	A01N, A01P, C05B, C05C, C05D, C05F, C05G, C06B, C06C, C06D, C06F, C09B, C09C, C09D, C09F, C09G, C09H, C09J, C09K, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C10N, C11B, C11C, C11D, C99Z
Chemistry	Materials, metallurgy	B22C, B22D, B22F, C01B, C01C, C01D, C01F, C01G, C03C, C04B, C21B, C21C, C21D, C22B, C22C, C22F
Chemistry	Surface technology, coating	B05C, B05D, B32B, C23C, C23D, C23F, C23G, C25B, C25C, C25D, C25F, C30B
Chemistry	Micro-structural and nano-technology	B81B, B81C, B82B, B82Y
Chemistry	Chemical engineering	B01B, B01D0001, B01D0003, B01D0005, B01D0007, B01D0008, B01D0009, B01D0011, B01D0012, B01D0015, B01D0017, B01D0019, B01D0021, B01D0024, B01D0025, B01D0027, B01D0029, B01D0033, B01D0035, B01D0036, B01D0037, B01D0039, B01D0041, B01D0043, B01D0057, B01D0059, B01D0061, B01D0063, B01D0065, B01D0067, B01D0069, B01D0071, B01F, B01J, B01L, B02C, B03B, B03C, B03D, B04B, B04C, B05B, B06B, B07B, B07C, B08B, C14C, D06B, D06C, D06L, F25J, F26B, H05H

Sector	Field	List of IPC codes
Chemistry	Environmental technology	A62C, B01D0045, B01D0046, B01D0047, B01D0049, B01D0050, B01D0051, B01D0052, B01D0053, B09B, B09C, B65F, C02F, E01F0008, F01N, F23G, F23J, G01T
Mechanical engineering	Handling	B25J, B65B, B65C, B65D, B65G, B65H, B66B, B66C, B66D, B66F, B67B, B67C, B67D
Mechanical engineering	Machine tools	A62D, B21B, B21C, B21D, B21F, B21G, B21H, B21J, B21K, B21L, B23B, B23C, B23D, B23F, B23G, B23H, B23K, B23P, B23Q, B24B, B24C, B24D, B25B, B25C, B25D, B25F, B25G, B25H, B26B, B26D, B26F, B27B, B27C, B27D, B27F, B27G, B27H, B27J, B27K, B27L, B27M, B27N, B30B
Mechanical engineering	Engines, pumps, turbines	F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02B, F02C, F02D, F02F, F02G, F02K, F02M, F02N, F02P, F03B, F03C, F03D, F03G, F03H, F04B, F04C, F04D, F04F, F23R, F99Z, G21B, G21C, G21D, G21F, G21G, G21H, G21J, G21K
Mechanical engineering	Textile and paper machines	A41H, A43D, A46D, B31B, B31C, B31D, B31F, B41B, B41C, B41D, B41F, B41G, B41J, B41K, B41L, B41M, B41N, C14B, D01B, D01C, D01D, D01F, D01G, D01H, D02G, D02H, D02J, D03C, D03D, D03J, D04B, D04C, D04G, D04H, D05B, D05C, D06G, D06H, D06J, D06M, D06P, D06Q, D21B, D21C, D21D, D21F, D21G, D21H, D21J, D99Z
Mechanical engineering	Other special machines	A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22B, A22C, A23N, A23P, B02B, B28B, B28C, B28D, B29B, B29C, B29D, B29K, B29L, B33Y, B99Z, C03B, C08J, C12L, C13B0005, C13B0015, C13B0025, C13B0045, C13C, C13G, C13H, F41A, F41B, F41C, F41F, F41G, F41H, F41J, F42B, F42C, F42D
Mechanical engineering	Thermal processes and apparatus	F22B, F22D, F22G, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24B, F24C, F24D, F24F, F24H, F24J, F25B, F25C, F27B, F27D, F28B, F28C, F28D, F28F, F28G
Mechanical engineering	Mechanical elements	F15B, F15C, F15D, F16B, F16C, F16D, F16F, F16G, F16H, F16J, F16K, F16L, F16M, F16N, F16P, F16S, F16T, F17B, F17C, F17D, G05G
Mechanical engineering	Transport	B60B, B60C, B60D, B60F, B60G, B60H, B60J, B60K, B60L, B60M, B60N, B60P, B60Q, B60R, B60S, B60T, B60V, B60W, B61B, B61C, B61D, B61F, B61G, B61H, B61J, B61K, B61L, B62B, B62C, B62D, B62H, B62J, B62K, B62L, B62M, B63B, B63C, B63G, B63H, B63J, B64B, B64C, B64D, B64F, B64G
Other fields	Furniture, games	A47B, A47C, A47D, A47F, A47G, A47H, A47J, A47K, A47L, A63B, A63C, A63D, A63F, A63G, A63H, A63J, A63K
Other fields	Other consumer goods	A24B, A24C, A24D, A24F, A41B, A41C, A41D, A41F, A41G, A42B, A42C, A43B, A43C, A44B, A44C, A45B, A45C, A45D, A45F, A46B, A62B, A99Z, B42B, B42C, B42D, B42F, B43K, B43L, B43M, B44B, B44C, B44D, B44F, B68B, B68C, B68F, B68G, D04D, D06F, D06N, D07B, F25D, G10B, G10C, G10D, G10F, G10G, G10H, G10K
Other fields	Civil engineering	E01B, E01C, E01D, E01F0001, E01F0003, E01F0005, E01F0007, E01F0009, E01F0011, E01F0013, E01F0015, E01H, E02B, E02C, E02D, E02F, E03B, E03C, E03D, E03F, E04B, E04C, E04D, E04F, E04G, E04H, E05B, E05C, E05D, E05F, E05G, E06B, E06C, E21B, E21C, E21D, E21F, E99Z

6.2 Technological fields: traditional defence sectors and KETs

The group of 11 technological clusters is derived from the concordance tables provided by the European Commission (2012) and Gkotsis and Vezzani (2016).

Table 29: Technological clusters and concordance with IPC classes

Sector	List of IPC codes
Weapons and ammunition	F41, F42
Transport vehicles: aircraft and aeronautics	B64B, B64C, B64D, B64F
Transport vehicles: ships	B63
Transport vehicles: railways, land vehicles, and others	B60, B61, B62
Aerospace	B64G
Nanotechnology	B82Y (previously Y01N), B81C, B82B
Photonics	F21K, F21V, F21Y, G01D 5/26, G01D 5/58, G01D 15/14, G01G 23/32, G01J, G01L 1/24, G01L 3/08, G01L 11/02, G01L 23/06, G01M 11, G01P 3/36, G01P 3/38, G01P 3/68, G01P 5/26, G01Q 20/02, G01Q 30/02, G01Q 60/06, G01Q 60/18, G01R 15/22, G01R 15/24, G01R 23/17, G01R 31/308, G01R 33/032, G01R 33/26, G01S 7/481, G01V 8, G02B 5, G02B 6 (excluding sub-classes 1/00 3/00 6/36 6/38 6/40 6/44 6/46), G02B 13/14, G03B 42, G03G 21/08, G06E, G06F 3/042, G06K 9/58, G06K 9/74, G06N 3/067, G08B 13/186, G08C 19/36, G08C 23/04, G08C 23/06, G08G 1/04, G11B 7/12, G11B 7/125, G11B 7/13, G11B 7/135, G11B 11/03, G11B 11/12, G11B 11/18, G11C 11/42, G11C 13/04, G11C 19/30, H01J 3, H01J 5/16, H01J 29/46, H01J 29/82, H01J 29/89, H01J 31/50, H01J 37/04, H01J 37/05, H01J 49/04, H01J 49/06, H01L 31/052, H01L 31/055, H01L 31/10, H01L 33/06, H01L 33/08, H01L 33/10, H01L 33/18, H01L 51/50, H01L 51/52, H01S 3, H01S 5, H02N 6, H05B 33
Biotechnology	C02F 3/34, C07C 29, C07D 475, C07K 2, C08B 3, C08B 7, C08H 1, C08L 89, C09D 11, C09D 189, C09J 189, C12M, C12P, C12Q, C12S, G01N 27/327 (except for co-occurrence with A01, A61, C07K 14/435, C07K 14/47, C07K 14/705, C07K 16/18, C07K 16/28, C12N 15/09, C12N 15/11, C12N 15/12, C12N 5/10, C12P 21/08, C12Q 1/68, G01N 33/15, G01N 33/50, G01N 33/53, G01N 33/68, G01N 33/566, C12N 1/19, C12N 1/21, C12N 1/15, C12N 15/00, C12N 15/10, C12P 21/02)
Advanced materials	B32B 9, B32B 15, B32B 17, B32B 18, B32B 19, B32B 25, B32B 27, B82Y 30, C01B 31, C01D 15, C01D 17, C01F 13, C01F 15, C01F 17, C03C, C04B 35, C08F, C08J 5, C08L, C22C, C23C, D21H 17, G02B 1, H01B 3, H01F 1/0, H01F 1/12, H01F 1/34, H01F 1/42, H01F 1/44, H01L 51/30, H01L 51/46, H01L 51/54
Micro and nano-electronics	G01R 31/26, G01R 31/27, G01R 31/28, G01R 31/303, G01R 31/304, G01R 31/317, G01R 31/327, G09G 3/14, G09G 3/32, H01F 1/40, H01F 10/193, H01G 9/028, H01G 9/032, H01H 47/32, H01H 57, H01S 5, H01L, H03B 5/32, H03C 3/22, H03F 3/04, H03F 3/06, H03F 3/08, H03F 3/10, H03F 3/12, H03F 3/14, H03F 3/16, H03F 3/183, H03F 3/21, H03F 3/343, H03F 3/387, H03F 3/55, H03K 17/72, H05K 1, B82Y 25

Sector	List of IPC codes
Advanced manufacturing technologies	B01D 15, B01D 67, B01J 10, B01J 12, B01J 13, B01J 14, B01J 15, B01J 16, B01J 19/02, B01J 19/08, B01J 19/18, B01J 19/20, B01J 19/22, B01J 19/24, B01J 19/26, B01J 19/28, B01J 20/30, B01J 21/20, B01J 23/90, B01J 23/92, B01J 23/94, B01J 23/96, B01J 25/04, B01J 27/28, B01J 27/30, B01J 27/32, B01J 29/90, B01J 31/40, B01J 38, B01J 39/26, B01J 41/20, B01J 47, B01J 49, B01J 8/06, B01J 8/14, B01J 8/24, B01J 10, B01L, B04B, B04C, B32B 37, B32B 38, B32B 39, B32B 41, B81C 3, B82B 3, B82Y 35, B82Y 40, C01B 17/20, C01B 17/62, C01B 17/80, C01B 17/96, C01B 21/28, C01B 21/32, C01B 21/48, C01B 25/232, C01B 31/24, C01B 9, C01C 1/28, C01D 1/28, C01D 3/14, C01D 5/16, C01D 7/22, C01D 9/16, C01F 1, C01G 1, C02F 11/02, C02F 11/04, C02F 3, C03B 20, C03B 5/24, C03B 5/173, C03B 5/237, C03B 5/02, C03C 21, C03C 29, C04B 11/028, C04B 35/622, C04B 35/624, C04B 35/626, C04B 35/653, C04B 35/657, C04B 37, C04B 38/02, C04B 38/10, C04B 40, C04B 7/60, C04B 9/20, C07C 17/38, C07C 2/08, C07C 2/46, C07C 2/52, C07C 2/58, C07C 2/80, C07C 201/16, C07C 209/82, C07C 213/10, C07C 227/38, C07C 231/22, C07C 249/14, C07C 253/32, C07C 263/18, C07C 269/08, C07C 273/14, C07C 277/06, C07C 29/74, C07C 303/42, C07C 315/06, C07C 319/26, C07C 37/68, C07C 4/04, C07C 4/06, C07C 4/16, C07C 4/18, C07C 41/34, C07C 41/58, C07C 45/78, C07C 45/90, C07C 46/10, C07C 47/058, C07C 47/09, C07C 5/333, C07C 5/41, C07C 51/42, C07C 51/573, C07C 51/64, C07C 57/07, C07C 67/48, C07C 68/08, C07C 7, C07D 201/16, C07D 209/84, C07D 213/803, C07D 251/62, C07D 301/32, C07D 311/40, C07D 499/18, C07D 501/12, C07F 7/20, C07H 1/06, C07K 1, C08B 1/10, C08B 17, C08B 30/16, C08C, C08F 2/01, C09B 41, C09B 67/54, C09D 7/14, C09J 5, C12M, C12S, C21C 5/52, C21C 5/54, C21C 5/56, C21C 7, C21D, C22B 11, C22B 21, C22B 26, C22B 4, C22B 59, C22B 9, C22C 1, C22C 3, C22C 33, C22C 35, C22C 47, C22F, C23C 14/56, C23C 16/54, C25B 9, C25B 15/02, C25C, C25D 1, C30B 15/20, C30B 35, C40B 60, D01D 10, D01D 11, D01D 13, D01F 9/133, D01F 9/32, D06B 23/20, D21H 23/20, D21H 23/70, D21H 23/74, D21H 23/78, D21H 27/22, F24J 1, F25J 3, F25J 5, F27B 17, F27B 19, F27D 19, F27D 7/06, G01C 19/5628, G01C 19/5663, G01C 19/5769, G01C 25, G01R 3, G11B 7/22, H01L 21, H01L 31/18, H01L 35/34, H01L 39/24, H01L 41/22, H01L 43/12, H01L 51/40, H01L 51/48, H01L 51/56, H01S 3/08, H01S 3/09, H01S 5/04, H01S 5/06, H01S 5/10, H05B 33/10, H05K 13, H05K 3
Cyphering, E-payment	G06F 12/14, G06F 21, G06K 19, G09C, G11C 8/20, G11C 16/22, H04K, H04L 9, H04M 1/66, H04M 1/663, H04M 1/665, H04M 1/667, H04M 1/67, H04M 1/673, H04M 1/675, H04M 1/68, H04M 1/70, H04M 1/727, H04N 7/167, H04N 7/169, H04N 7/171, H04W 12, G06Q 20, G06Q 30/00, G06Q 30/02, G06Q 30/04, G06Q 30/06, G06Q 30/08, G06Q 40, G07F 7/08, G07F 7/10, G07F 7/12, G07G 1/12, G07G 1/14, H04L 12/14, H04M 15, H04M 17, H04W 4/24

6.3 Defence assignees, lower level of consolidation

Table 30: Top 20 innovators by number of patent families in the identified sample (2002-12)

Rank	Assignee name	Country	Count of families	Perc.	Cumul.
1	THALES	FR	3,197	5.0%	5.0%
2	RAYTHEON CO	US	3,118	4.9%	9.9%
3	US GOVT NAVY	US	2,814	4.4%	14.3%
4	LOCKHEED CORP	US	2,772	4.4%	18.7%
5	BAE	UK	1,872	2.9%	21.6%
6	AGENCY DEFENCE DEV KOREA	KR	1,677	2.6%	24.2%
7	US GOVT ARMY	US	1,396	2.2%	26.4%
8	HARRIS CORP	US	1,312	2.1%	28.5%
9	NORTHROP GRUMMAN	US	1,238	1.9%	30.4%
10	QINETIQ LTD	UK	671	1.1%	31.5%
11	RHEINMETALL	DE	663	1.0%	32.5%
12	SAMSUNG THALES CO LTD	KR	651	1.0%	33.6%
13	KOREA AEROSPACE IND LTD	KR	625	1.0%	34.5%
14	LIG NEX1 CO LTD	KR	622	1.0%	35.5%
15	AIRBUS DEFENCE AND SPACE	EU	488	0.8%	36.3%
16	L3 TECHNOLOGIES	US	486	0.8%	37.0%
17	SAAB	SE	486	0.8%	37.8%
18	US GOVT AIRFORCE	US	480	0.8%	38.6%
19	SAGEM DEFENSE SEC	FR	472	0.7%	39.3%
20	DIEHL BGT DEFENCE GMBH & CO	DE	406	0.6%	39.9%

Table 31: Top 20 patent owners by number of inventions 2002-07 on the left, and 2008-12 on the right.
(*The last column reports the change in the relative share between the first and the second period)*

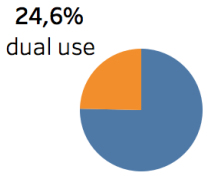
Rk.	2002 – 2007			2008 – 2012			Change in perc.
	Assignee name	Ctry	Perc.	Assignee name	Ctry	Perc.	
1	LOCKHEED CORP	US	4.9%	RAYTHEON CO	US	5.6%	**1.48%**
2	US GOVT NAVY	US	4.8%	THALES	FR	5.6%	**1.21%**
3	THALES	FR	4.4%	AGENCY DEFENCE DEV KOREA	KR	4.3%	**3.37%**
4	RAYTHEON CO	US	4.2%	US GOVT NAVY	US	4.0%	-0.79%
5	NORTHROP GRUMMAN	US	3.0%	LOCKHEED CORP	US	3.8%	-1.08%
6	US GOVT ARMY	US	2.5%	BAE	UK	3.4%	**0.86%**
7	BAE	UK	2.5%	US GOVT ARMY	US	1.8%	-0.68%
8	HARRIS CORP	US	2.3%	HARRIS CORP	US	1.8%	-0.55%
9	QINETIQ LTD	UK	1.4%	LIG NEX1 CO LTD	KR	1.7%	**1.49%**
10	KOREA AEROSPACE IND LTD	KR	1.0%	SAMSUNG THALES CO LTD	KR	1.4%	**0.72%**
11	RHEINMETALL	DE	1.0%	AIRBUS DEFENCE AND SPACE	EU	1.2%	**0.90%**
12	AGENCY DEFENCE DEV KOREA	KR	1.0%	RHEINMETALL	DE	1.1%	**0.10%**
13	US GOVT AIRFORCE	US	0.9%	KOREA AEROSPACE IND LTD	KR	0.9%	-0.07%
14	L3 TECHNOLOGIES	US	0.9%	EADS	EU	0.9%	**0.59%**
15	SAAB	SE	0.9%	NORTHROP GRUMMAN	US	0.9%	-2.07%
16	DIEHL BGT DEFENCE GMBH & CO	DE	0.7%	SAGEM	FR	0.8%	**0.12%**
17	GUP KB PRIBOROSTROENIJA	RU	0.7%	QINETIQ LTD	UK	0.7%	-0.73%
18	SAGEM	FR	0.7%	BELL HELICOPTER TEXTRON	US	0.7%	**0.33%**
19	SAMSUNG THALES CO LTD	KR	0.7%	SAAB	SE	0.6%	-0.27%
20	RAFAEL ADVANCED DEF SYS	IL	0.6%	L3 TECHNOLOGIES	US	0.6%	-0.27%

6.4 Dual use: details on selected technological fields

The following pages report summary statistics on dual use cases for a selection of technological fields identified through the WIPO concordance table. They report the trend in terms of share of dual use out of total defence innovations, the evolution of the relative shares of the priority countries, the top five patent portfolio holders, and the heat maps for Europe and the USA showing the proportion of dual use in those regions with at least 10 patented inventions in the years 2002-12.

Weapon and ammunition

(F41 and F42)



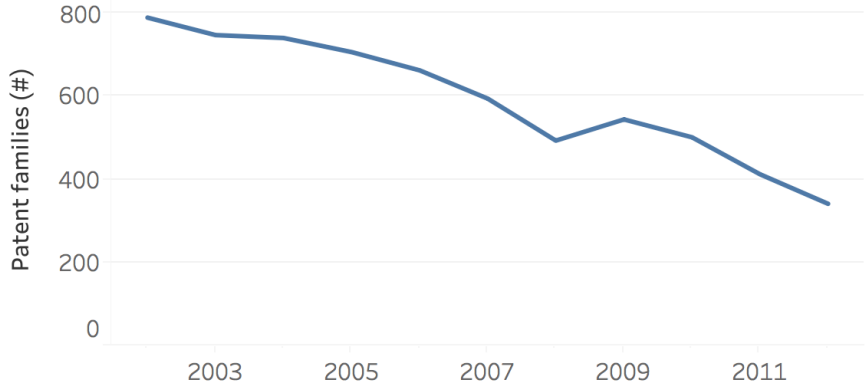
Assignees by dual use patent families

	Families	Perc.
RAYTHEON CO	183	2,8%
US GOVT NAVY	115	1,8%
US GOVT ARMY	108	1,7%
LOCKHEED CORP	79	1,2%
BOEING CO	76	1,2%

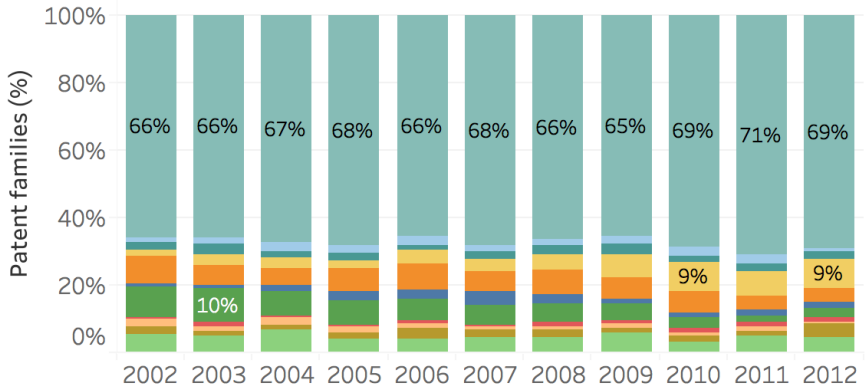
Priority country

- United States
- Japan
- France
- WIPO
- United King..
- Israel
- South Korea
- Russia
- Germany
- Others
- EPO

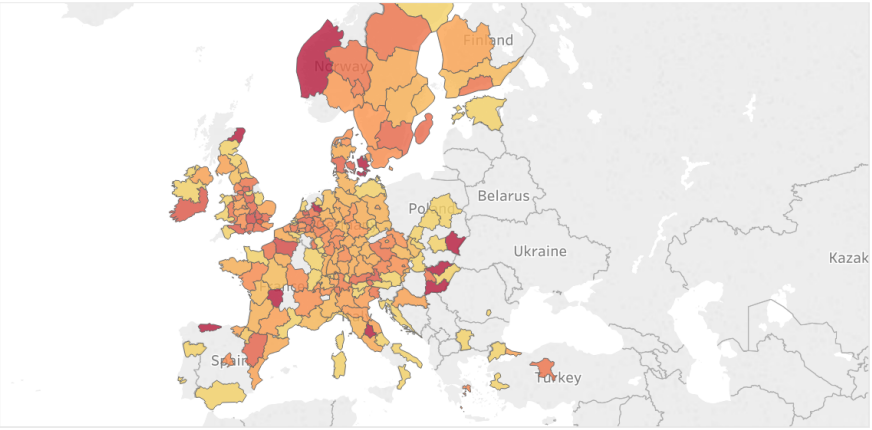
Trend of dual use patent families by priority year



Priority countries of dual use patent families by priority year



Map of the share of dual use patent families in EU regions (NUTS2) for the selected technology cluster



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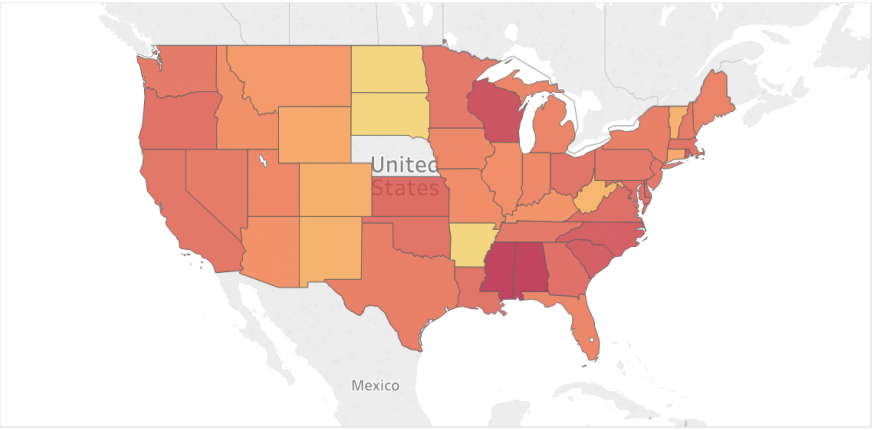
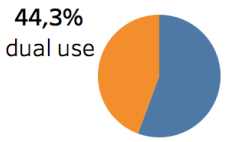


Transport



Assignees by dual use patent families

	Families	Perc.
LOCKHEED CORP	259	7,4%
THALES	248	7,1%
US GOVT NAVY	203	5,8%
RAYTHEON CO	128	3,7%
SIKORSKY AIRCRAFT C..	119	3,4%

Priority country

- United States
- Japan
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- United King..
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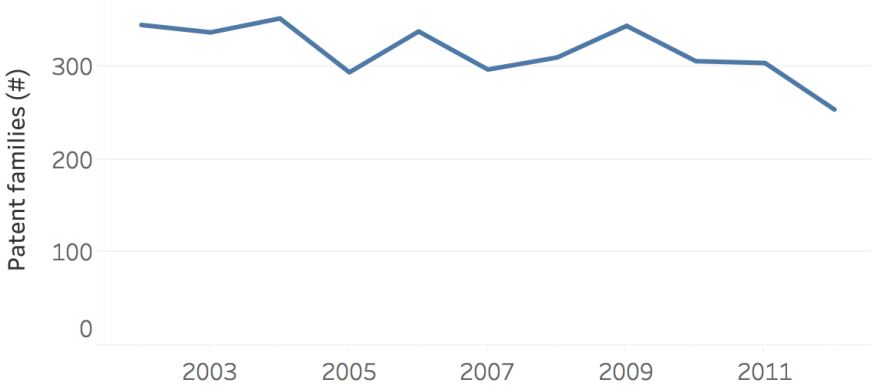
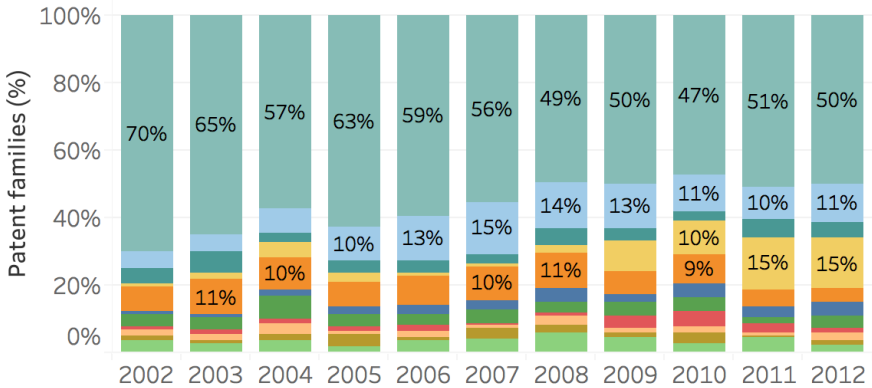
- South Korea
- Russia
- Germany
- Others
- EPO

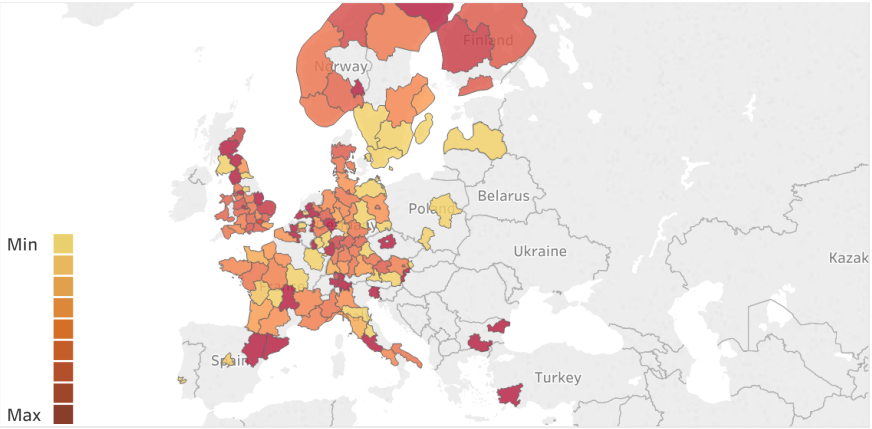
Trend of dual use patent families by priority year



Priority countries of dual use patent families by priority year



Map of the share of dual use patent families in EU regions (NUTS2) for the selected technology cluster



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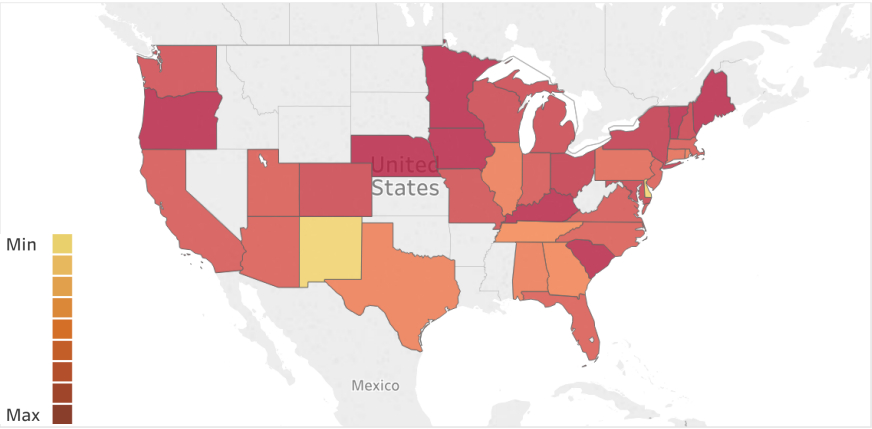

Telecommunications

61,4%
dual use

Assignees by dual use patent families

	Families	Perc.
HARRIS CORP	537	16,2%
RAYTHEON CO	435	13,1%
LOCKHEED CORP	333	10,1%
THALES	322	9,7%
BAE	221	6,7%

Priority country
- United States
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- United King..
- Israel
- South Korea
- Russia
- Germany
- Others
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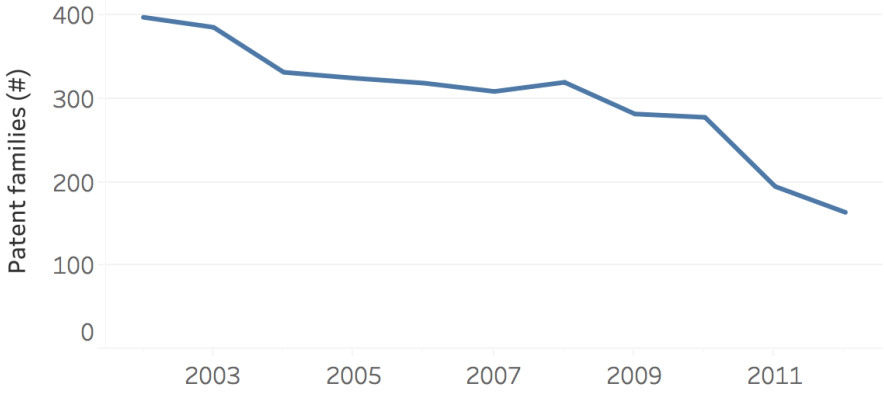
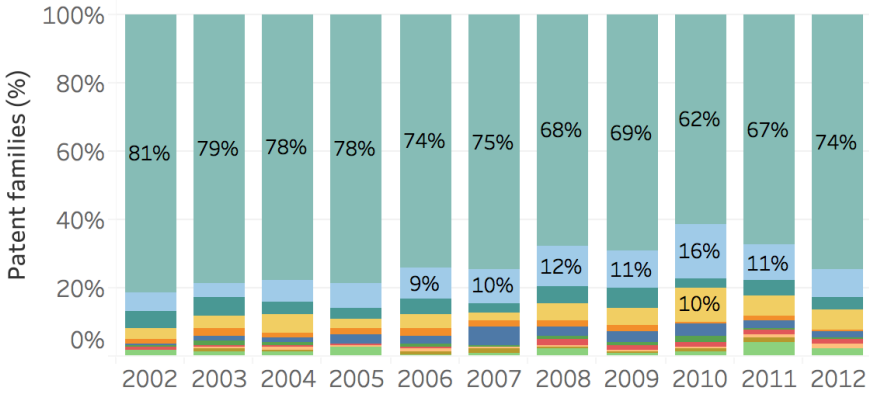
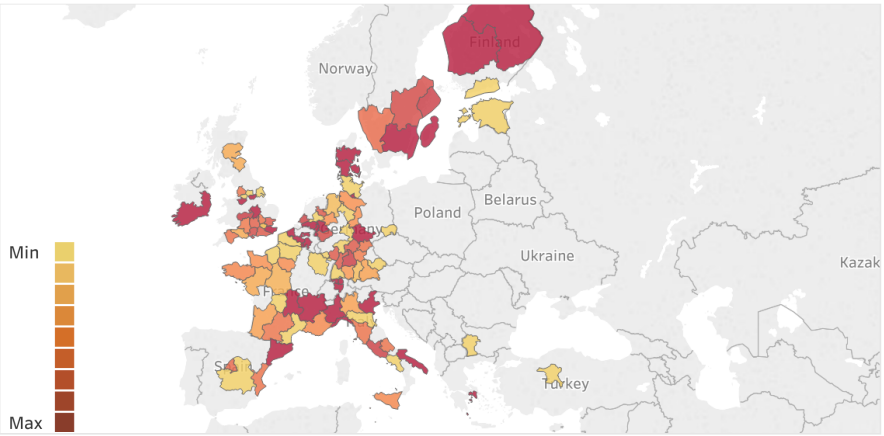
Trend of dual use patent families by priority year



Priority countries of dual use patent families by priority year



Map of the share of dual use patent families in EU regions (NUTS2) for the selected technology cluster



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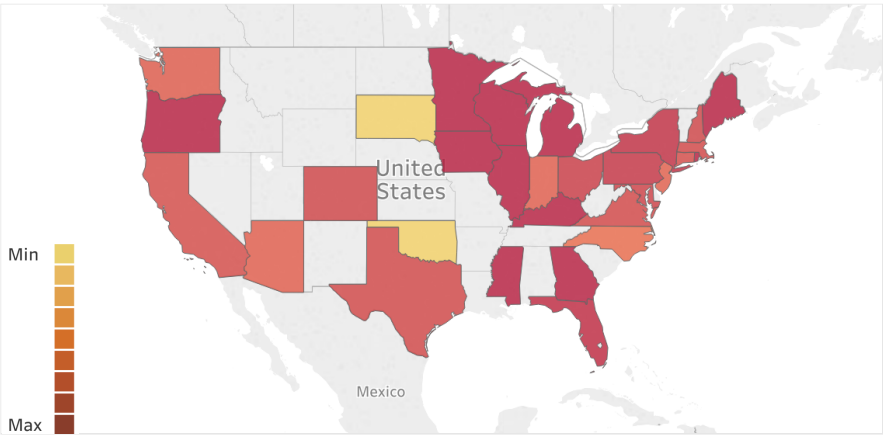
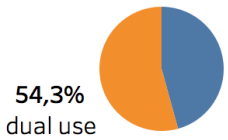


Optics



Assignees by dual use patent families

	Families	Perc.
RAYTHEON CO	246	14,0%
LOCKHEED CORP	161	9,2%
NORTHROP GRUMMAN	157	9,0%
BAE	141	8,0%
US GOVT NAVY	122	7,0%

Priority country

- United States
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- Germany
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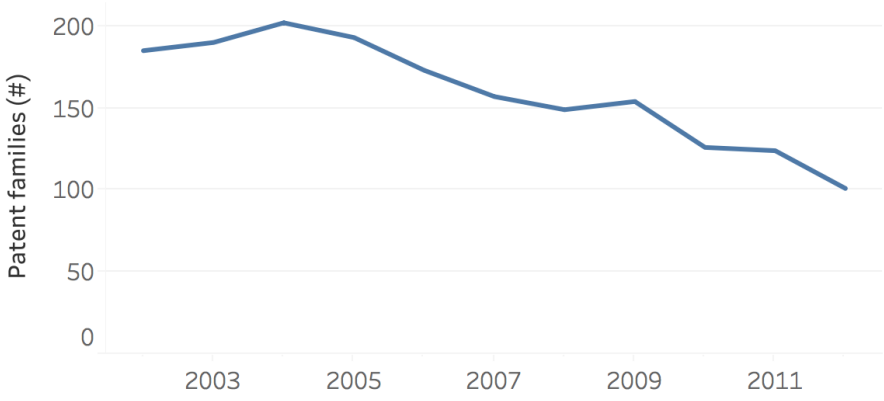
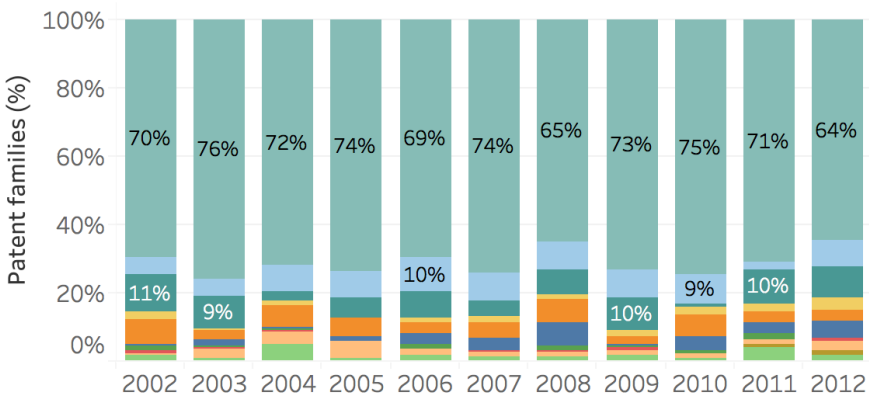
Trend of dual use patent families by priority year



Priority countries of dual use patent families by priority year



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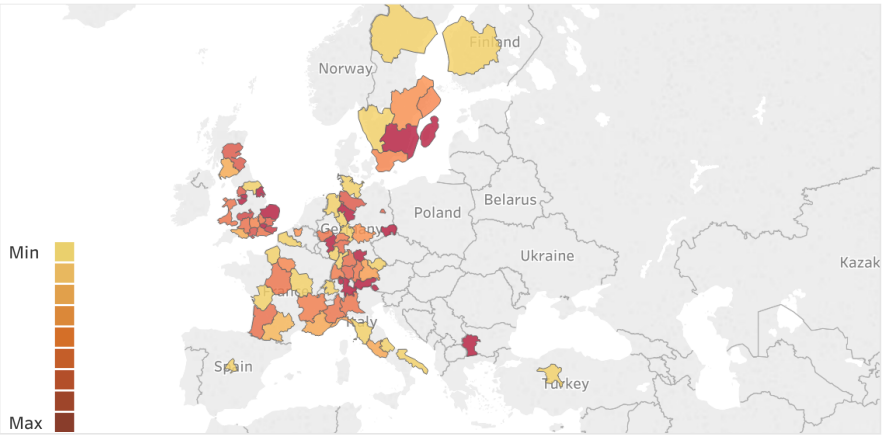

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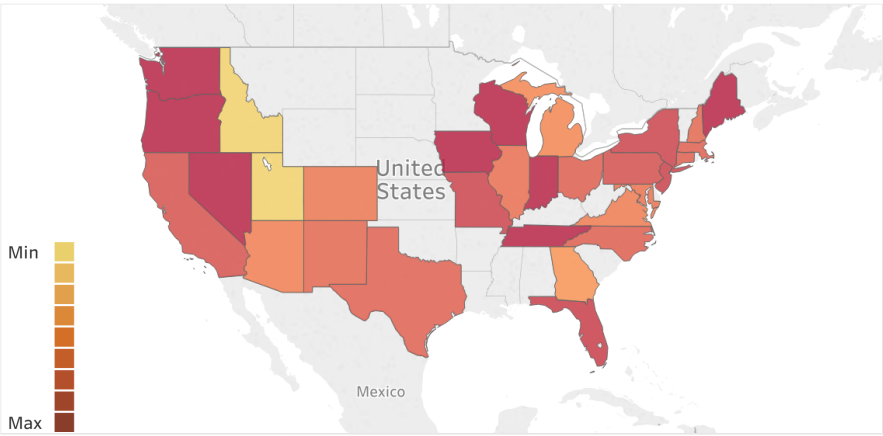

Medical technology

66,8%
dual use

Assignees by dual use patent families

	Families	Perc.
US GOVT ARMY	40	7,9%
US GOVT NAVY	37	7,3%
RAYTHEON CO	24	4,7%
LOCKHEED CORP	18	3,6%
NORTHROP GRUMMAN	15	3,0%

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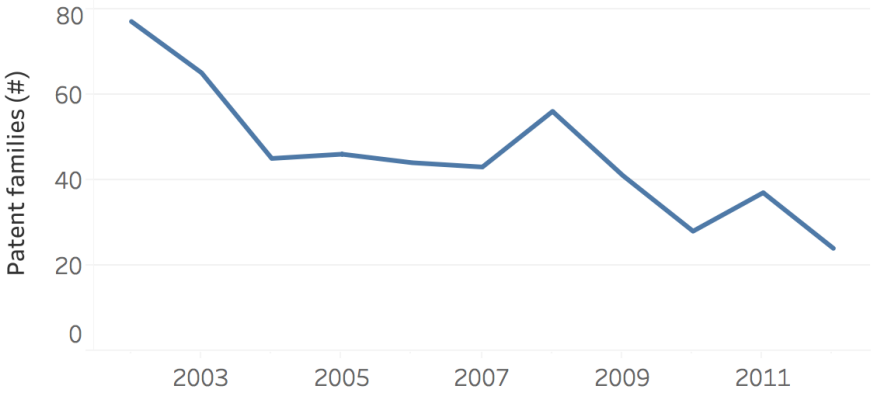

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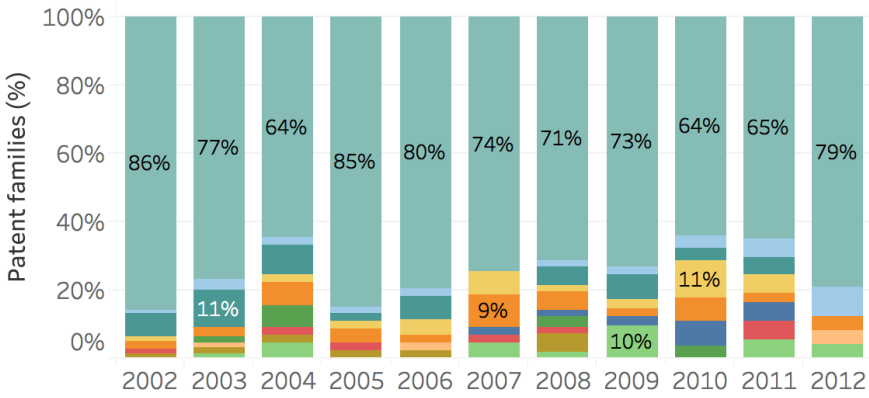

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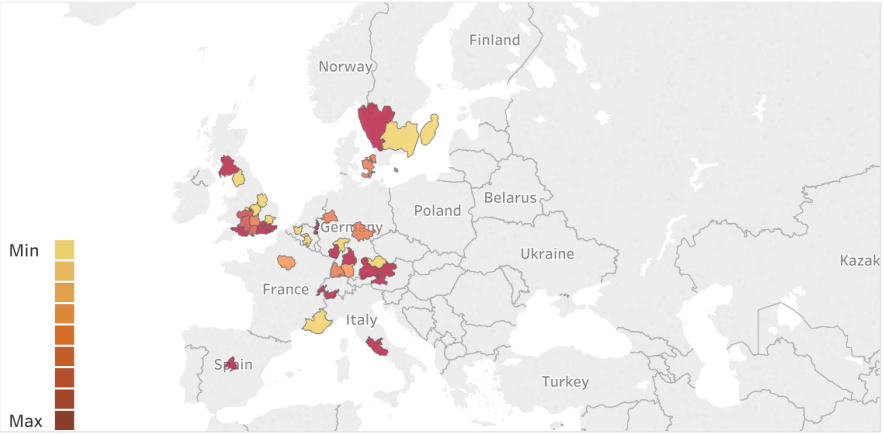

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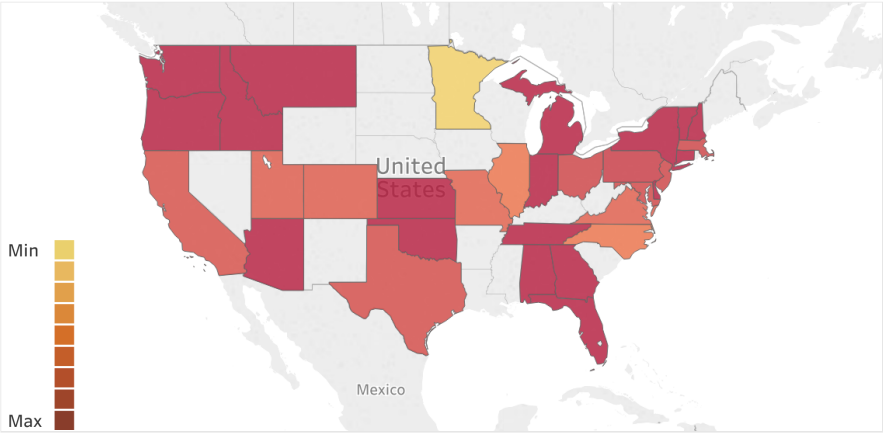

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