Investigating the capabilities and the competitiveness of the EU vis-à-vis its main competitors in developing civilian technologies with critical spillovers into the defence

European Commission

JRC TECHNICAL REPORTS

Investigating the capabilities and the competitiveness of the EU vis-à-vis its main competitors in developing civilian technologies with critical spillovers into the defence.

Caviggioli F, De Marco A, Scellato G

2020

Contact information
Name: Alexander Tuebke
Address: Edificio Expo – C/ Inca Garcilaso 3 – 41092 Seville (Spain)
Email: alexander.tuebke@ec.europa.eu
Tel.: +34 954 488 326

EU Science Hub
https://ec.europa.eu/jrc

JRC120293

PDF ISBN 978-92-76-17893-4 doi:10.2760/78635

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Caviggioli F., De Marco A., Scellato G., *Investigating the capabilities and the competitiveness of the EU vis-à-vis its main competitors in developing civilian technologies with critical spillovers into the defence*, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17893-4, doi:10.2760/78635, JRC120293

Contents

Abstract

This study proposes a framework for investigating the relevance of dual use inventions, i.e., military applications of civilian patents. The data collected extends the companion report that focused on the opposite direction of dual use: from military inventions to civilian applications (Caviggioli et al., 2018). The analyses focus on 10 million patent families from selected patent offices in the years 2002-2015. The method proposed identified 85,034 defence inventions (0.9%) that were compared with the civilian inventions along several dimensions (time, geography, technological clusters). This study operationalises dual use from both a civilian to a military application (CM dual use) and in the opposite direction (MC dual use). The presence of CM dual inventions is 1.4% of the total civilian sample, with a slightly decreasing trend. They are four times the MCs in absolute numbers. The geographical analysis reveals heterogeneity: the US is the origin of 58.7% of the total dual use inventions identified in the sample and shows the highest incidence of cases (4.7% of all civilian inventions). The results also indicate significant heterogeneity in the share of domestic knowledge flows. The domestic spillover for dual in most of the countries examined is lower than for non-dual: a military application of a civilian innovation is a relatively more frequent occurrence outside the borders of the country with the exceptions of the USA, France, and the Russian Federation. The share of domestic CM dual use in the EU28 area is 36%, smaller than the corresponding non-dual value (42%).

1 Introduction

Aims

This study extends the results of the previous companion study that proposed a method of identifying defence innovations and dual use cases from patent data (Caviggioli et al., 2018). The time frame of the analyses has been expanded to the years 2002-15 and dual use is now detected both when considering the "from military to civilian" and the opposite direction. The method has been tested on a large sample of patent data from twelve of the largest patent offices. The data collected was analysed in order to develop a set of statistics providing quantitative insights on the magnitude of dual use and the characteristics of national innovation frameworks.

The study presented in this paper aims to provide empirical support in the debate on the public and private R&D investments in defence in Europe. The European Commission considers defence and internal security to be highly relevant to EU member states and an area where cooperation needs to be fostered. The aggregate EU28 expenditure on defence and security was estimated to be to 227 billion Euro in 2017, less than half the value of the USA, but still a non-negligible area of investment whose trend is increasing (EC, 2017a). The growth of R&D in the commercial sector, the increased availability of access to knowledge sources, and the great degree of interconnection and capillarity in the innovation and production networks suggest that innovations in the defence sector might build upon technologies initially developed in a civilian context (Kepe et al., 2018).

In this regard, this study specifically aims to provide data driven insights into the intensity of knowledge spillovers from civilian sector to military applications, with a comparative perspective across different countries.

Method

Following Caviggioli et al. (2018), this study combines various strategies for identifying defence innovations. The selected data sources are patent repositories, which although bearing some well-known limitations, guarantee wide coverage (in time, geography, and technological areas) and 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), International Patent Classification (IPC) codes, and the presence of military keywords in patent text fields. For the identification of dual use cases, the method exploits relationships across the patent citation network. The information available in the SIPRI database is used to characterize "hybrid" companies, i.e., firms with less than 50% of revenues derived from arms sales, and the patents they own.

Data and findings

The method proposed analysed 10 million patent families from selected patent offices for the years 2002-2015 and identified 220,858 defence patents corresponding to 85,034 families (0.9% of the whole sample). Patents belonging to "hybrid" companies (i.e. with arms sales below 50% of total revenues) represent 4.8% of the total sample. The yearly number of new civilian patent families slightly decreased in the years examined while hybrid and military inventions increased by 4% and 30% respectively (the sample does not include Chinese patents).

Concerning military innovations, the geographical distribution and the technological composition across the WIPO sectors are consistent with the previous results (Caviggioli et al., 2018). The USA is the largest source of patented defence innovations and alone accounts for a share equal to the sum of South Korea, the Russian Federation, France, Germany, Japan, and UK (approximately 43%). The combined share of the largest European countries by number of defence innovations, that is, France, Germany, UK, Italy, Poland, Spain, Sweden, Austria, and Finland amounts to 20% of all of the military inventions.

The analyses on the technological composition of civilian, hybrid, and military samples reveal similarities such as the relevance of "Computer technology", and specificities: hybrid patents have a similar distribution to the civilian sample but due to the identification method, they show a relevant presence in “Engines, pumps, turbines” and “Transport”; as expected the defence innovations are concentrated in “Other special machines” (42.3%), which includes “Weapons and ammunition”. The presence of military innovations in “Computer Technology” is non-negligible (9.8%) but is also lower than in the civilian (11.7%) and hybrid sample (16.8%).

Focusing on the knowledge base of the military inventions identified, a shift was observed from the technological base covered by fields like “Chemical engineering”, “Telecommunications”, and “Textile and paper machines” to a more intense use of inventions not only in “Other special machines (incl. Weapon and Ammunition)” but also in “Transport” and “Computer technology”. The results suggest a potential trend of increasing specialization as military patents are increasingly based on defence technology innovations with the significant exception of the use of “Computer technology” as a source of new developments. Comparison of 2002-08 with 2009-15 shows an increased incidence of the “core” military knowledge base, from 14.2% to 17.2%, rather than in the larger pool of civilian technological fields.

Dual use was identified in both the case from a civilian to a military application (CM dual use) and in the opposite direction (MC dual use). The presence of CM dual inventions is 1.4% of the total civilian sample. This percentage increases to 3.4% in the hybrid sample as expected from a group of firms partly involved in military activities. CM dual use cases in the aggregate civilian and hybrid sample represent 1.5% of the total non-military patents. All the analyses suggest the presence of a slightly decreasing trend of CM dual use (from 1.6% in 2002 to 1.3% in 2009). Note that given the very large base of civilian patents filed every year, a 1.5% incidence of CM dual use case has to be regarded as a non-negligible share.

The authors advance some potential preliminary drivers explaining the result: i) the defence companies absorbed civilian technologies and competences. These companies have developed internal competencies that make them less dependent on external sources of knowledge; ii) at the aggregate level the two domains, “civilian” and “military” are less and less permeable but some technological sectors reveal a higher share of dual use cases in recent years (especially in the area of Mechanical Engineering); iii) the time window required for the translation of a new civilian innovation into an innovative military application is increasing to the result of technological complexity or specialization.

The CM dual inventions are four times the MCs in absolute numbers. The share of CM dual use on the civilian sample is 1.5% while the share of MC dual use on the corresponding military sample is approximately 50%. This huge difference seems to be driven by the large intrinsic difference between the size of civilian and military samples (as denominators and as citing reference pools). In fact, when weighting the number of potential citing patents, the relative presence of CM dual use is 3.6 times higher than MC.

Among the technological fields where CM dual use seems to occur most, the smallest field by number of inventions developed, “Micro-structural and nano-technology” (5.2%) is highlighted but this also shows the highest decrease in the period examined (-2.25%). The whole area of “Electrical engineering” (in particular “Basic communication processes” and “Telecommunications”, 3.6% each) favours the emergence of spillovers from civilian to military domains and vice-versa as identified in the previous study about civilian applications of defence inventions (Caviggioli et al., 2018). The area of “Mechanical engineering” reports an increase in the relative presence of CM dual use (in particular: “Engines, pumps, turbines” (+0.25%), “Transport” (+0.19%), “Machine Tools” (+0.19%)).

The regions with the highest share of CM dual use cases are very similar to those found for MC. The evidence suggests that on average the inventions developed in certain geographical areas have a “dual” nature more frequently than in other regions. The largest patent office is the USPTO with 58.7% of the total dual use inventions identified in the sample, and the share of CM dual use on total civilian inventions in the USA is 4.7%.

From the patent citation network, we generated a matrix of knowledge flows which highlights the presence of spillover within and across countries. The results suggest a significant heterogeneity in the share of domestic knowledge flows. In most of the countries the domestic spillover for dual is lower than for non-dual. This finding suggests that a military application of a civilian innovation is relatively more frequent to occur outside the country’s borders. This is different in US, France and the Russian Federation, where the share of domestic CM dual spillover is higher than the domestic civilian use. The share of domestic CM dual use in the EU28 area is 36%, smaller than the corresponding non-dual value (42%).

The USA represents a neat outlier, being the most likely to subsequently transform the civilian research output into domestic military applications. When considering the geographical area of the EU28, the data shows a relatively high presence of local civilian innovations that become dual inside the EU28 borders. This result is only partly driven by the intra-national phenomenon (such as in France and Germany). The values for the other larger member countries (e.g. Austria, Italy, Spain, and Sweden) are lower than the value of the aggregate EU28: it suggests the presence of a within-EU-borders effect, having a civilian invention developed in one of the member state and then used in military applications by a different member country.

The overall data reinforces the evidence about the significant bi-directionality of the knowledge flows from civilian to military sectors in the US context.

The companies with the largest number of civilian inventions that have a subsequent military application are IBM, Samsung, and Microsoft with CM dual use ranging from 1.5 to 5.5% of their portfolio. Motorola (10.5%) and Boeing (9.6%) also show a relatively higher share.

The top 20 CM dual use “converters”, those responsible for transforming previous civilian inventions into defence innovations, include two hybrid companies, and two US and one South-Korean defence agencies. The company responsible for the largest share of dual use cases is Raytheon (7.2% of the total sample of dual cases). Almost the whole patent portfolio of Exelis (92%), Bell Helicopter Textron (84%), and Harris (81%) is based on previous civilian inventions. On the contrary, a group of assignees that includes the US and South Korean defence agencies reports a portfolio share of approximately 50% or below (e.g., BAE, Northrop Grumman, and Qinetiq).

Open issues and future developments

Future research could address the limitations of this work and improve the identification of defence innovations and of dual use cases starting from the method proposed. 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 expenditure on defence) 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.

2 Literature review

The current study builds on the companion work of 2018 "Assessing the innovation capability of EU companies in developing dual-use technologies" (Caviggioli et al., 2018). The previous results have been coherently extended in this project by analysing the relevance of dual use cases and focusing on the spillover effects from civilian technologies to subsequent military applications.

Caviggioli et al. (2018) described the research framework of dual-use innovations thoroughly. The most relevant aspects are summarised in this section, and in the light of the scope and goals of this study, recent contributions are included.

The scientific literature was analysed by searching the titles and abstracts of published peer-reviewed articles in the Scopus and Web of Knowledge electronic reference retrieval services, using a set of keywords that cover the topics under scrutiny. Complementary documents have been found in Internet searches in order to collect reports about the general context of the defence sector.

Framework: defence and dual use

Defence and internal security are among the main dimensions along which the EU can foster cooperation and commonalities between member states (EC, 2017a and 2017b). EU28 spending in defence and security is estimated to be approximately 227 billion Euros. It represents a non-negligible area of investment in the context of public procurement although it is less than half the 600 billion Euro value for the USA (EC, 2017a).

Most of the studies in the existing literature on the defence sector tackle the subject from the perspective of the political framework, investigating decisions about the investment and expenditure levels, and the impact on economic growth, with mixed evidence (Morales-Ramos, 2002; Mowery, 2010).

The relationship with civilian R&D not only shows complex dynamics in terms of economic growth but also when studying innovation activities (Mowery, 2010). 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 term "dual use" is usually applied with different interpretations when considering the relationship between military and civilian innovations (Watkins, 1990; Molas-Gallart, 1997; Oltmann, 2015; Bukkvoll et al., 2017; Martí Sempere, 2018): co-development of products, civilian application of a military artifact or diffusion of a military technology (or vice versa), and trade regulation[1] of sensible products. What is shared by the various concepts is the capacity to assimilate technologies from other sectors (Watkins, 1990).

Anecdotal evidence suggests that research activities carried out by military companies and government agencies may have a significant impact on the civilian sector and society at large (e.g., the Global Positioning System - GPS, the Internet, the cavity magnetron). However, dual use technologies may also be represented by innovations developed for civilian purposes that are susceptible to military applications. The growth of R&D in the commercial sector, the increased availability of access to knowledge sources, the great degree of interconnection and capillarity in the innovation and production networks suggest that the innovations in the defence sector might significantly build on technologies initially developed in a civilian context (Kepe et al., 2018).

In the past implementation of ICT in weapons systems increased the level of technological complexity, changing defence technological systems (Lazaric et al., 2011). Focusing on the expected future scenarios, the European Defence Agency (EDA) identifies a wide range of new technologies that are expected to influence the future capability requirements of the defence sector in Europe[2]. These broad technological areas include artificial intelligence, additive manufacturing, communications systems, nanotechnologies, sensors, and advanced smart materials. A large amount of R&D in these areas has been and is currently being carried out by civilian companies and research institution, with part of the innovation investment supported by governmental budgets. In this regard, the results of this project can contribute to informing the policy debate on the indirect impact of R&D funding in the civilian sector on the innovative output of the military sector in the EU.

[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] Further details available at: https://www.eda.europa.eu/Aboutus/how-we-work/expert-teams/capability-technology-areas (accessed February 2019).

In the past the literature mainly focused on dual use as an application of a military-originated technology into the perimeter of the civilian sector. Some studies tried to understand the relationship between defence and civilian R&D and analysed case studies at the national level to derive evidence on the policies applied from a wider perspective that includes cooperation between the defence and civilian domains.

In addition, Te Kulve and Smit (2003) analysed the cooperation strategy adopted in The Netherlands that aimed to develop a new battery with both civilian and military applications. The network created was rather loose with no overarching binding actor and limited persistence.

The analysis of the governance mechanisms used by the national defence agencies provides some additional evidence on the changed framework of innovation activities and the increasing role of new developments from the civilian technological domain. Lazaric et al. (2011) examined the variation in the approach of the French Defence Agency, facing the changes in the innovation process. The sources of change are commonly identified in the national innovation system and the sectoral system of innovation. However, since knowledge and capabilities are more distributed and new developments require ever increasing recombination from different technical areas, public and private actors need to collaborate. Avadikyan and Cohendet (2009) focused on the British Ministry of Defence (MoD) to study the approach used to transfer technology and found a gradual change in the goals of the activities pursued. At first, the initiatives of the MoD were designed to exploit military projects and spin-off their results to society. Later, the MoD promoted civilian-military collaborations and related organisational and institutional forms, following an approach of spin-in for the purpose of broadening the R&D base of the military sector. The policy adopted consisted of raising the awareness of civilian companies, especially SMEs, of defence programs as a potential outlet for their innovations.

Empirical studies

Empirical studies on dual use are scarce and have limitations (Schmid, 2017, Lee and Sohn, 2017). It seems that none of the previous analyses investigated the composition of the knowledge base of the defence innovations.

Most of the previous literature on technology spillovers and on the relationship between military and civilian R&D with the economy and the innovation activities has been carried out using case studies (Alic et al. 1992; Smith, 1994; Maclin et al., 1994; Te Kulve and Smit, 2003; Avadikyan, Cohendet, and Dupouët 2005; Bellais and Guichard 2006; Kim et al., 2016).

In fact, previous empirical studies suffer from various limitations. In particular, only a subsample of the total innovations produced by the defence sector is publicly available in patents and publications.

Very few studies employed a quantitative identification strategy to collect data on defence innovations and relied on IPC codes: the IPC classes F41 and F42, concerning weapons and ammunition (Acosta et al., 2011; Lee and Sohn, 2017) and a few other IPC codes relevant to the defence sector (Acosta et al., 2017). The use of military-specific IPC codes provides a robust identification strategy and excludes false positive results: only a few technologies which are not developed by defence firms nor have specific military applications are included in the classes F41 and F42 (e.g., inventions on airbag charges or toy weapons). The main limitation of the approach is that the perimeter of the technological domain does not cover all the fields where defence companies are active. Traditional defence companies also invest and develop inventions in fields outside the scope of weapons and ammunitions (e.g. air or naval vessels, structures, or engines, special fabrics, communication and networking devices). This limitation has already been pointed out by previous studies (Lee and Sohn, 2017; Schmid, 2017)[3] and has been addressed in the work of Caviggioli et al. (2018) by including military firms and keyword-based searches in the identification strategy.

Once the defence innovations have been detected, the empirical strategy requires a method of assessing the dual use concept. Previous empirical work 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 to military IPC codes only), civilian patents (associated to non-military IPC codes only), and mixed patents (patents with both military and civilian IPC codes). Acosta et al. (2017) and Schmid (2017) expanded

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

the identification strategy by including a set of defence firms[4]. The study by Caviggioli et al. (2018) considered those cases to be dual when a defence innovation is cited by a forward civilian application. The patent citation network has previously been exploited by scholars to study the diffusion of military technologies (Schmid, 2017; Acosta et al., 2017; Lee and Sohn, 2017). Knowledge diffusion from military to civilian patents is more likely to occur when the source invention is associated to both military and civilian IPC codes (Acosta et al., 2017), when the technological scope is wider, and the innovation is developed in collaboration with research organisations (Enger, 2013). Concerning the value of the innovations (proxied by patent renewals), Lee and Sohn (2017) found that military inventions are of higher quality when dual.

Very few empirical studies focus on the opposite direction of spillover that is from civilian to areas of military application. Kuzyk et al. (2017) combined macroeconomic indicators and survey results to study the case of Russian universities as a particular civilian source of knowledge for the defence industry. Although the largest part of the innovative output cannot be immediately categorized as defence innovations and limitations in the technical development process and contractual issues can hinder the transfer of technologies, the authors found that universities have great potential for developing dual purpose research. In their case study on unmanned aerial vehicles (UAV), Kim et al. (2016) analysed the citation network of patents. UAV technologies were originally developed for reconnaissance flights and as targets for surface-to-air weapons, and they were subsequently introduced in civilian fields (e.g. agriculture, telecommunications, and oil production). The authors selected UAV patents and evaluated the spillover across different technological sectors: even though a clear distinction of civilian and military applications is not used, the data shows the presence of relevant spillovers across fields.

[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).

3 Method used to identify defence innovations and dual use

General approach and purpose of the study

The main objective of the study is to provide quantitative evidence on dual use technologies with a specific focus on civilian to military applications and on the cross fertilisation between these areas. The analysis proposed involved the adoption of a method that was developed in the previous project JRC/SVQ/2017/B.3/0032/NC (Caviggioli et al., 2018) initially based on the identification of military patents and then on dual use inventions, relying on citation flows.

Based on patent data, this research provides estimates of the impact of Key Enabling Technologies developed in a civilian context on the subsequent development of technological innovations in the military domain. It is worth recalling that patents only represent a partial subset of innovations, and this limitation in the case of defence inventions is also related to those patentable inventions that are kept secret due to their sensitive nature and in the interests 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 work has relied on alternative approaches based on case studies[5], but these do not permit large scale and comprehensive analysis.

The results of this project will contribute to understanding the dynamics and interplay between civilian R&D investment and the diffusion of civilian-originated innovations into innovative solutions developed by the military sector. The study presented in this article adopts a global scale, allowing comparison between major economies in terms of the dynamics of technological spillovers from the civilian to the military sector.

Data source and scope

Patent documents were searched and identified in patent data repositories. PATSTAT[6] was relied on as the main repository, and Clarivate/Derwent Innovation was used as a source of support information.

The time window examined covers the years from 2002 to 2015, based on the priority date of patents. It should be noted that the most recent years are underestimated due to the presence of delays in patent publication and electronic availability.

The patent citation network was exploited by backward reference to other patent documents with the aim of analysing the knowledge base of defence innovations. The authors relied on their categorization method based on company names, IPC codes, and keywords in order to discriminate between military and civilian patent families filed in recent years, that is, with a priority filing in 2002 or afterwards. The identification of the military and civilian domains for older patents (i.e., with a priority year before 2002) only relies on the criterion based on IPC codes. This approach does not depend on the availability of the textual contents in patent documents and on the identification of companies operating in the defence sector before recent years (which would not have been possible since data on arms sales are not available before 2002), providing a consistent and robust selection strategy.

The geographical scope of the queries took the main patent offices into consideration, which was composed of all the offices of the member countries of the EPC, EPO, USPTO, JPO, KIPO, and those of Canada, Russia, Israel, and India. Although bearing some limitations in scope and in the identification of military companies in certain areas (i.e., Chinese players), this approach conveyed a much more robust identification strategy when analysing firm names, corporate trees, and citation flows.

Method

This section explains the method used to identify dual use innovations. The approach is based on the previous project JRC/SVQ/2017/B.3/0032/NC (Caviggioli et al., 2018). The process has been further refined by additional consistency checks. Data has also been updated and extended.

[5] By way of example: Hartley, K. (2006).

[6] We used the 2018 Autumn Edition of PATSTAT published by the European Patent Office.

The approach consists of a multistep method that relies on patent repositories as data source. The following paragraphs provide details on the methodological steps, coherently with those proposed in the previous project:

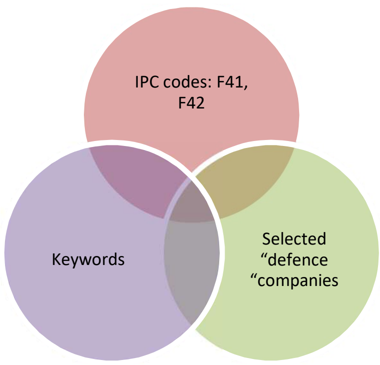
- Step 1: Identification of defence innovations
- Step 2: From patents to patent families
- Step 3: Identification of dual use patents
- Step 4: Focus on the backward citations of military patents
- Step 5: Consistency check.

Step 1: Identification of defence innovations

The first set of activities aims to identify defence patents. The procedural steps that define the inclusion of an invention in the defence category were developed in the previous project JRC/SVQ/2017/B.3/0032/NC (Caviggioli et al., 2018). The time coverage was extended to 2015. It should be note that the most recent years in the sample can still be affected by patent publication delays.

Patents have been tagged as part of the defence sector if they satisfy at least one of the following three requirements. It should be borne in mind that some of the patents satisfy more than one admission condition (Figure 1).

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



A. Presence of military IPC codes

The patent is associated to any of the IPC codes belonging to classes F41 “Weapons”, or F42 “Ammunition; Blasting”. These codes are mainly applied to inventions developed for warfare applications. Previous studies applied this very same technique (Acosta et al., 2011). Following a more inclusive approach in the present study, additional IPC codes directly associated with the defence industry were searched for which were included in the previous project (Table 1).

Table 1 List of IPC codes selected as defence specific

Source	IPC code	Description
Acosta et al. (2017)	A62D 101/02	Chemical warfare substances
JRC/SVQ/2017/B.3/ 0032/NC	B21D 51/54	Making hollow cartridge-case objects, e.g., for ammunition, for letter carriers in pneumatic-tube plants
JRC/SVQ/2017/B.3/ 0032/NC	B21K 21/04	Shaping thin-walled hollow articles, e.g., cartridges
JRC/SVQ/2017/B.3/ 0032/NC	B21K 21/06	Shaping thick-walled hollow articles, e.g., projectiles
JRC/SVQ/2017/B.3/ 0032/NC	B21K 21/14	Closed or substantially-closed ends, e.g., cartridge bottoms
JRC/SVQ/2017/B.3/ 0032/NC	B60R 7/14	Stowing or holding appliances inside a vehicle [...] e.g., travelling articles, or maps. Disposition of racks, clips, or similar for supporting weapons
JRC/SVQ/2017/B.3/ 0032/NC	B63G	Offensive or defensive arrangements on vessels; mine-laying; mine-sweeping; submarines; aircraft carriers
JRC/SVQ/2017/B.3/ 0032/NC	B64D 1/04	Dropping, ejecting, releasing, or receiving articles, liquids, or similar in flight ...the articles being explosive
JRC/SVQ/2017/B.3/ 0032/NC	B64D 1/06	Dropping, ejecting, releasing, or receiving articles, liquids, or similar in flight; Bomb releasing; Bomb doors
JRC/SVQ/2017/B.3/ 0032/NC	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
JRC/SVQ/2017/B.3/ 0032/NC	G01S 1/42	Conical-scan beam beacons transmitting signals [...], e.g., for "beam-riding" missile control
JRC/SVQ/2017/B.3/ 0032/NC	G01S 19/18	Satellite radio beacon positioning systems; Determining position, velocity, or attitude using signals transmitted by such systems. Military application
JRC/SVQ/2017/B.3/ 0032/NC	G06G 7/80	Analogue computers for specific processes, systems, or devices, e.g., simulators; for gun-laying; for bomb aiming; for guiding missiles

B. Patent assignee is a military firm

The patent belongs to the portfolio of a company that mainly operates in the defence sector. The identification of companies dealing with military products relied on two main sources: the SIPRI Arms Industry Database[7] and the Register of the Certified Defence-related Enterprises (CERTIDER)[8]. Only those defence companies with core activities in the defence industry were considered. The parameter for the identification of military companies is the ratio of arms sales on the total sales. The identification threshold considers those companies with at least 50% of their revenues deriving from arms sales to be military. Accordingly, all of the patents owned by a defence company are considered to be defence inventions. This approach determined the exclusion of two types of false positive results:

i. Large corporations active in several business and technological fields (e.g. General Electric) for which only a small fraction of patents in the portfolio are related to military activities.

ii. Vehicles such as aircraft, helicopters, and ships have a dual use by nature since they can be used in both warfare and civilian applications (transportation of goods and people, rescue, and medical assistance).

The names of the selected companies have been searched in the assignee field of the patent database. This task took potential name changes, spelling errors, acronyms, etc. ("name game") into account.

The process excluded all those firms listed in the SIPRI database but with relative small arms sales, i.e., below 50%. However, all the patents belonging to these "hybrid" companies have been identified in order to check the robustness of the method when considering dual use cases: the patented inventions belonging to these firms are referred to as "hybrid" patents.

C. Patent text fields containing military specific keywords

The patent is considered to be a defence invention whenever it contains one of the keywords defined in the project JRC/SVQ/2017/B.3/0032/NC (Caviggioli et al., 2018). The authors searched for the main text fields (Title, Abstract, and Claims) of patent documents. The list of keywords is shown in Table 17 in the Appendix. Each concept has been searched for by controlling for stemming, different spellings, and excluding board or other type of games (IPC class A63 "Sports; Games; Amusements"; keywords in Title Abstract or Claims: "game", "toy", "sport")[9].

Step 2: From patents to patent families

Once the patents have been labelled with the "defence" tag, a more accurate level of analysis was carried out by applying INPADOC patent families instead of single patents. Patent families are considered to be a more precise measurement of inventive activities and avoid duplications when counting patent documents extended to multiple offices. The process led to the identification of "defence" patent families.

The use of families also helped in drawing up a more accurate representation of the patent citation network that was then used to operationalise the definition of dual use (see the next step).

Step 3: Identification of dual use patents

The third step aimed to identify patents with a potential dual use. Operationalization of the definition of "dual use" relies on the patent citation network. The approach has greater reliability compared to alternative methods based on the co-occurrence of a small number of IPC codes considered to be "defence-specific" (mainly F41 and F42) with any other IPC code[10].

[7] The SIPRI arms industry database contains information on the 100 largest arms-producing and military services companies and it is publicly available here: https://www.sipri.org/databases (last access in January 2019).

[8] The register includes more than 50 European companies and is available at: http://ec.europa.eu/growth/tools-databases/certider/index.cfm (last access in January 2019).

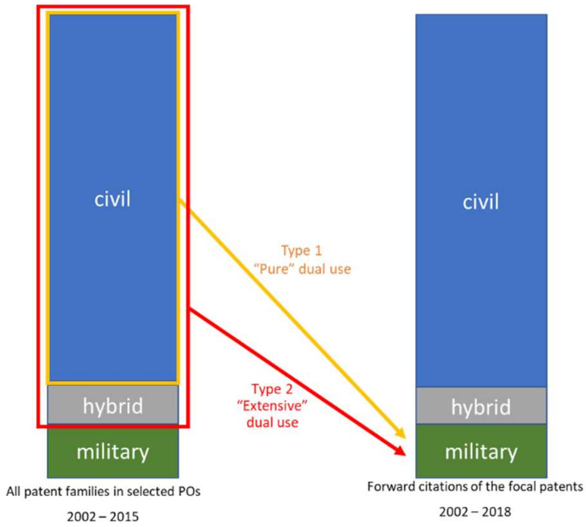
[9] Further details are available in the companion report JRC/SVQ/2017/B.3/0032/NC (Caviggioli et al., 2018).

[10] 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 considers all those patents reporting F41 ("Weapons ") and G02 ("Optics ") as dual use inventions. Among those patents, a large number of which focus on missile seekers, guidance systems, and weapon targeting

The patent citation network was examined to assess the direction of dual use and identify civilian innovations that contributed to subsequent defence innovations. Military patents with civilian backward citations were considered to be dual use cases. Or on the other hand, civilian patents cited by a defence innovation are defined as dual use cases.

Figure 2 represents the approach for the identification of dual use. Military and hybrid patent families were identified in the previous steps. The residual category is the civilian group of innovations. All of the civilian patents with at least a forward citation from a military innovation are considered to be "dual". In particular, this type of dual use is labelled "pure" to distinguish it from the other case that is based on the inclusion of hybrid patents in the pool: this second group is defined as "extensive" dual use. In other words, "pure" dual use occurs whenever a civilian innovation finds application in a subsequent military patent family. The "extensive" dual use scenario refers to a starting invention that is either civilian or belongs to a company that is partially involved in arms sales. Consequently, a higher incidence of dual cases of the "extensive" rather than the "pure" type is expected.

Figure 2 Diagram summarising the process identifying dual use families (from civilian to defence applications)



The method based on citations introduces a truncation effect on the identification of dual use patents. Patents filed in more recent years have a smaller time window to receive citations than older ones. Patents filed at the beginning of the period examined are exposed to a higher "risk" of receiving a citation than recent inventions. Consequently, the forward citations with a five-year limit after the reference date of the cited invention were examined. This approach makes it possible to compare data on citations across years, and so data on the identification of dual use. Although some information is lost, the results are improved with increased reliability in the years between 2002 and 2009: the tail of five years was excluded plus one or two years accumulated as delay between the priority and publication date. As a robustness check, the analyses also provide the results with alternative time windows.

Step 4: Focus on the backward citations of military patents

One of the analyses focuses on the composition of the knowledge base that constitutes prior art for military inventions. Since the identification method is limited to the years 2002-15, a second approach based only on the IPC criterion was introduced, which was not as accurate but had extended time coverage. The procedural steps are the following:

- All of the patents were classified as military according to the presence of a defence IPC code in the whole PATSTAT database.

tools, for which a civilian application, if possible, is expected to require a substantial modification that is more likely to be embedded in a new patent application.

- For the military patents in the years 2002-15 the backward citations and the technological fields they belong to were reconstructed.
- We distinguished across military and civilian prior art on the base of the IPC code criterion.

This approach provides a consistent and robust condition that does not depend on the availability of patent texts and on the identification of defence companies, which would not have been possible since data on arms sales are not available for years longer ago in the past.

Step 5: Consistency check

The patents resulting from the application of the method for the identification of defence and dual use patents were checked manually. The reliability of the selection criteria was tested by reading the description of a randomly-selected sample of patents. This activity supported the accuracy of the method and helped in adjusting the identification strategy accordingly. By way of example, the analyses of the IPC codes A45B 3/14 ("Sticks with weapons") and G03B 29 ("Combinations of cameras, [...] with non-photographic non-optical apparatus, e.g. clocks or weapons") were not considered as sufficient condition for the identification of defence patents due to the predominance of civilian inventions according to the actual description of the patents retrieved. The search for assignees that include the term "defence" was refined by excluding those mentioning "la defense" in the company name (i.e. the district in Paris). Keywords like "tank" or "defence" were not a reliable selection criterion returning a consistent number of civilian patents.

Concepts and definitions

Labels are used in the following paragraphs to address the main concepts of this study for the purpose of making the reading easier. They are listed in Table 2 and summarise the operationalisation of duality I this study using the patent citation network and the identification of the nature, either civilian or military, of the patent families for the origin and the citing invention, respectively.

Table 2 Summary of the terms used in this study to address the concepts of dual use according to the method proposed.

Concept – label	Dual use	Description
CC civilian use	No	A civilian (or hybrid) patent family whose forward citations are all civilian (or hybrid) patent families (no citations from military patent families). Applications of the source knowledge remain in the civilian domain; no spillover to military applications.
MM military use	No	A military patent family whose forward citations are all military patent families (no citations from civilian or hybrid patent families). Applications of the source knowledge remains in the military domain; no spillover to civilian applications.
CM dual use	Yes	A civilian (or hybrid) patent family with at least one military forward citation. It represents a knowledge spillover from the civilian to the military domain.
MC dual use	Yes	A military patent family with at least one civilian (or hybrid) forward citation. It represents a knowledge spillover from the military to the civilian domain.
Domestic CC civilian use	No	A citation from a civilian (or hybrid) patent family to a civilian (or hybrid) patent family having the same priority Patent Office. Selection of applications of a source knowledge remaining in the civilian domain and in the same geographical area.
Domestic CM dual use	Yes	A citation from a military patent family to a civilian (or hybrid) patent family having the same priority Patent Office. It represents a knowledge spillover from the civilian to the military domain remaining in the same geographical area.

4 Description of the data

The sample examined focused on selected POs between 2002 and 2015, and consists of approximately 25 million patents, corresponding to almost 10 million patent families.

The aim of the present study is to analyse the presence of civilian inventions that constitute a starting point for subsequent military patents. Civilian patents are identified as the residual group from the classification of military inventions (as explained in section 0).

Civilian inventions account for a total of 9.5 million patent families (94.3% of the total sample). The defence inventions number 85,034 (0.9%). The identification process also made it possible to highlight those patents belonging to "hybrid" companies, that is, firms reported in the SIPRI database having arms sales below the 50% threshold of total revenues. The sample contains 484,602 families (4.8% of the total inventions) owned by any of these "hybrid" companies.

Composition of the sample of defence innovations

The method used to identify defence innovations generated a dataset of 220,858 patents which correspond to 85,034 patent families in the years 2002-15. Table 3 provided details on the distribution of the records collected across the search criteria proposed: each patent is either owned by a defence company, associated to a military IPC code, or includes defence specific keywords. The composition of the sample is coherent with the results of the previous study (Caviggioli et al., 2018).

Although there is a non-negligible overlapping across the entry criteria, the choice of the different selection conditions contributes incrementally to the generation of the database. The largest contribution comes from the application of the "firm" criterion: 45% of the patent families are owned by defence firms and, at the same time, they do not report military-specific IPC codes or keywords. On the other hand, the inclusion of inventions with defence IPC codes only contributes 26% of the 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, suggesting a limited marginal contribution.

Table 3 Description of the database according to the application of the selection criteria applied

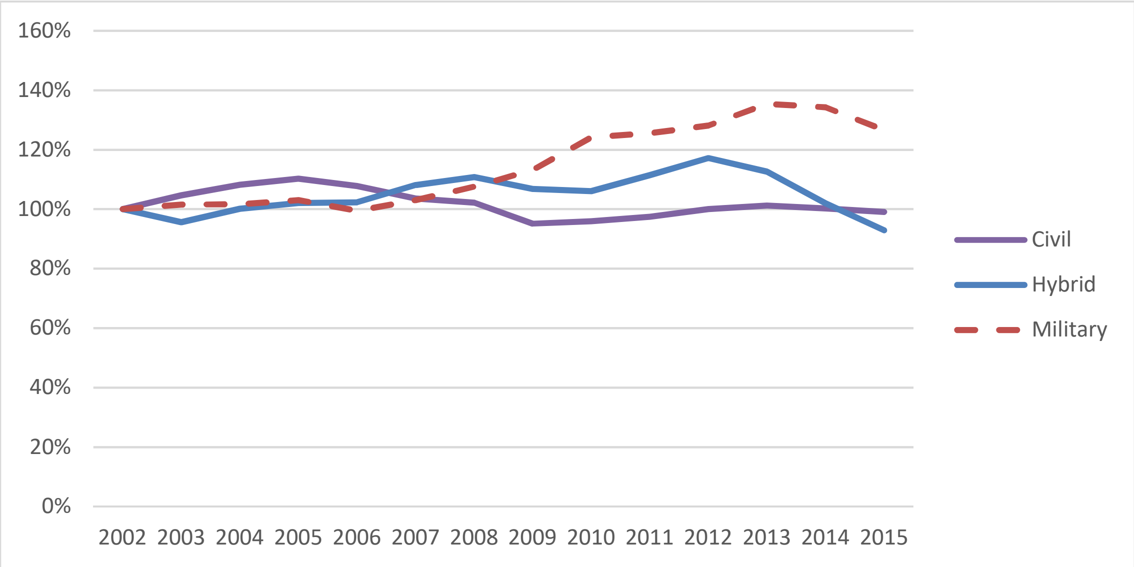
Selection criteria			Patents	Perc. tot. patents	Patent families	Perc. tot. patent fam.
firm	IPC	keyword				
Y	Y	Y	7,844	3.6%	3,469	4.1%
Y	Y	N	16,232	7.3%	4,625	5.4%
Y	N	Y	1,567	0.7%	835	1.0%
N	Y	Y	22,438	10.2%	11,657	13.7%
Y	N	N	110,399	50.0%	38,497	45.3%
N	Y	N	54,957	24.9%	21,704	25.5%
N	N	Y	7,421	3.4%	4,247	5.0%
Total			**220,858**	**100.00%**	**85,034**	**100.00%**

Concerning the overlapping across the proposed criteria, the contemporary presence of "IPC" and "keyword" represent 14% of the total database. Only 4% of the inventions identified satisfy all three conditions at the same time.

Time trend

Figure 3 shows the yearly variation in patent families for each type of innovations starting from the year 2002 (priority year). Comparing the starting and the final three-year periods, the number of civilian patent families decreased by 4% while hybrid and military inventions increased by 4% and 30% respectively. It is worth remembering that the analysed sample does not include Chinese patents because the booming numbers of patents from China are the main drivers of the global increase in patenting activities.

Figure 3 Change in the number of patent families for each type of inventions (civilian, hybrid, and military) in the Pos selected starting from the year 2002.



Geographical scope of defence innovations

The geographical scope of the patent families in the sample of defence innovations is analysed in this section by examining their priority countries. The geographical scope is driven by the collection method that focuses on a selection of the most relevant world patent offices with the exclusion of the Chinese PO.

The priority country represents the origin of the innovation, and is considered to be 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 of defence innovations in the sample, representing 80% of all inventions. Furthermore, 43% of all patent families were initially filed in the USA while France, Germany, the UK, Italy, Poland, Spain, Sweden, Austria, and Finland are the most frequent priority countries in Europe and represent 20% of the sample in terms of patent families (an additional 2% of the selected inventions have a priority at the EPO).

The results are very similar to the findings of the previous study (Caviggioli et al., 2018).

Table 4 The first 20 priority offices by number of defence patent families.

Rank	Priority country	Families	Perc.on total defence sample
1	USA	37,434	43.3%
2	South Korea	10,688	12.3%
3	Russian Federation	8,394	9.7%
4	France	7,102	8.2%
5	Germany	5,465	6.3%
6	Japan	3,410	3.9%
7	United Kingdom	3,311	3.8%
8	EPO	1,953	2.3%
9	Israel	1,099	1.3%
10	PCT filing (WIPO)	1,019	1.2%
11	Italy	982	1.1%
12	Poland	624	0.7%
13	Spain	402	0.5%
14	Sweden	392	0.5%
15	Canada	295	0.3%
16	Australia	249	0.3%
17	Austria	208	0.2%
18	Finland	207	0.2%
19	Taiwan	143	0.2%
20	Turkey	141	0.2%
	OTHERS	1,516	1.8%

Technological fields of military and civilian patents

The aim of this section is to examine the composition of the knowledge base of the civilian and defence innovations, i.e., those technological sectors that include and originate the innovative output in the corresponding technological domain.

Two types of analyses are presented. Firstly, the distribution of the patent families across the technological space is examined in sub-section 0: the tables compare the presence of civilian, hybrid, and military innovations in technological clusters.

Secondly, sub-section 0 reports the results of the analyses on the sectoral composition of the backward citations of the military patents. The application of "Step 4" of the method provide a preliminary aggregate evaluation of the presence of civilian patents in the prior art of defence innovations, representing their knowledge base.

Distribution across technological sectors

The database of defence innovations is described in terms of technological clusters based on the IPC codes associated with the patents identified. The analysis is carried out by applying the WIPO concordance table that maps all of the inventions identified in the technological space. The methodological section provides detail about the concordance between IPC codes and technological fields.

The descriptive statistics on the distribution of defence patented innovations across technological fields are shown in Table 5. The columns "Civilian", "Hybrid", and "Military" report the relative share of inventions in each technological cluster across the three categories. It is possible to highlight those fields that represent the largest group contributing to each category. In the sample examined (selected POs in the years 2002-15), civilian innovations were mainly developed in "Computer technology" (11.7%), "Electrical machinery, apparatus, energy" (10.2%), and "Audio-visual technology" (8.1%). The largest fields where hybrid companies were patenting are similar to the civilian ones, i.e., those related to ICT: "Computer technology" (16.8%) and "Electrical machinery, apparatus, energy" (13.9%). The data also shows a high presence in "Engines, pumps, turbines" (11.8%) and "Transport" (11.2%) according to the process for the definition of hybrid companies which in many cases operate in the aeronautics sector. Concerning the defence innovations, the largest presence of innovations is in "Other special machines" (42.3%), which includes "Weapons and ammunition", i.e. IPC codes F41 and F42. Other relevant fields are "Measurement" (16.0%), and "Transport" (13.8%).

Although "Computer Technology" includes a non-negligible number of military patents (9.8%), this share is lower than the corresponding values for civilian and hybrid categories. On the contrary, fields like "Measurement", "Transport", "Telecommunications", and "Control" show a relatively high presence of defence innovations than in the civilian category.

Table 5 Distribution of patent families according to the WIPO Concordance table. The table reports the share of civilian, hybrid, and military families across technological sectors for the selected sample of patent offices in the years 2002-2015. Percentages above 10% are shown in bold.

Sector	Field number	Field description	Civil	Hybrid	Military
Electrical engineering	01	Electrical machinery, apparatus, energy	**10.2%**	**13.9%**	5.7%
	02	Audio-visual technology	8.1%	9.8%	5.0%
	03	Telecommunications	5.8%	9.6%	8.4%
	04	Digital communication	5.2%	9.6%	4.7%
	05	Basic communication processes	1.5%	2.5%	2.3%
	06	Computer technology	**11.7%**	**16.8%**	9.8%
	07	IT methods for management	2.8%	3.1%	0.9%
	08	Semiconductors	6.8%	8.9%	2.7%
Instruments	09	Optics	7.1%	4.6%	5.3%
	10	Measurement	6.7%	9.6%	**16.0%**
	11	Analysis of biological materials	1.1%	0.5%	0.7%
	12	Control	3.5%	6.4%	5.7%
	13	Medical technology	5.2%	2.8%	1.3%
Chemistry	14	Organic fine chemistry	2.9%	0.4%	0.8%
	15	Biotechnology	2.3%	0.3%	0.8%
	16	Pharmaceuticals	2.9%	0.1%	0.6%
	17	Macromolecular chemistry, polymers	2.5%	0.6%	0.7%
	18	Food chemistry	2.2%	0.1%	0.1%
	19	Basic materials chemistry	3.4%	1.6%	2.5%
	20	Materials, metallurgy	2.9%	2.6%	2.0%
	21	Surface technology, coating	3.6%	2.9%	3.4%
	22	Micro-structural and nano-technology	0.5%	0.5%	0.6%
	23	Chemical engineering	3.8%	2.7%	2.1%
	24	Environmental technology	2.6%	2.8%	1.4%
Mechanical engineering	25	Handling	4.3%	5.1%	2.3%
	26	Machine tools	3.7%	4.3%	3.2%
	27	Engines, pumps, turbines	3.7%	**11.8%**	3.0%
	28	Textile and paper machines	3.3%	1.7%	1.3%
	29	Other special machines	4.9%	2.3%	**42.3%**
	30	Thermal processes and apparatus	2.7%	4.5%	1.1%
	31	Mechanical elements	4.8%	5.5%	3.4%
	32	Transport	7.2%	**11.2%**	**13.8%**
Other fields	33	Furniture, games	5.1%	1.2%	1.0%
	34	Other consumer goods	3.6%	1.7%	2.9%
	35	Civil engineering	5.7%	3.2%	4.2%

Note: field "29 – Other special machines" includes weapons and ammunition (IPC codes: F41 and F42). These technical classes are entirely associated with the military sample according to the selection criterion.

Table 6 shows the relative growth in each technological cluster between the beginning (2002-04) and the end (2013-15) of the period examined distinguishing between the type of innovations (civilian, hybrid, or military). The largest increase in civilian technological cluster occurs the following fields: "Micro-structural and nano-technology" (54.4%), "IT methods for management" (49.0%), and "Digital communication" (47.2%). Please note that the first of these three is a very small field.

Within the hybrid innovations, the highest growth rates are found in fields in the Mechanical Engineering area and "Civilian engineering" (increase of more than 50%). In particular, the presence of military patent families increased in the areas of Electrical and Mechanical Engineering.

Table 6 Growth of technology clusters according to the WIPO Concordance table. The table reports the increase in the years 2013-15 compared to 2002-04 in each category: civilian, hybrid, and military. Growth above +40% is shown in bold.

Sector	Field number	Field description	Civil	Hybrid	Military
Electrical engineering	01	Electrical machinery, apparatus, energy	20.1%	5.7%	**55.5%**
	02	Audio-visual technology	-26.5%	-52.6%	**97.2%**
	03	Telecommunications	-35.4%	-49.5%	-3.7%
	04	Digital communication	**47.2%**	-3.6%	**88.3%**
	05	Basic communication processes	-25.3%	-45.7%	-18.4%
	06	Computer technology	15.1%	-32.7%	**64.8%**
	07	IT methods for management	**49.0%**	-21.6%	**77.6%**
	08	Semiconductors	-14.1%	-32.3%	7.6%
Instruments	09	Optics	-27.0%	-52.1%	16.0%
	10	Measurement	14.9%	19.0%	**43.3%**
	11	Analysis of biological materials	-0.5%	20.5%	-10.1%
	12	Control	10.9%	10.3%	**93.2%**
	13	Medical technology	18.4%	29.6%	0.8%
Chemistry	14	Organic fine chemistry	-17.7%	-11.8%	-25.6%
	15	Biotechnology	-4.0%	-34.3%	-37.3%
	16	Pharmaceuticals	-6.2%	-50.4%	-19.3%
	17	Macromolecular chemistry, polymers	-5.4%	-35.7%	8.9%
	18	Food chemistry	16.3%	-57.6%	-53.8%
	19	Basic materials chemistry	1.7%	22.4%	1.7%
	20	Materials, metallurgy	2.3%	11.9%	**40.3%**
	21	Surface technology, coating	-9.5%	-8.4%	-2.7%
	22	Micro-structural and nano-technology	**54.4%**	-3.1%	**74.7%**
	23	Chemical engineering	-3.8%	10.4%	-18.7%
	24	Environmental technology	-12.9%	15.5%	-28.5%
Mechanical engineering	25	Handling	-11.6%	-5.9%	**55.5%**
	26	Machine tools	-10.2%	14.8%	-13.3%
	27	Engines, pumps, turbines	4.0%	**67.1%**	**127.2%**
	28	Textile and paper machines	-39.0%	-34.4%	9.5%
	29	Other special machines	-3.5%	**55.6%**	27.1%
	30	Thermal processes and apparatus	-7.5%	39.2%	35.0%
	31	Mechanical elements	8.1%	**52.0%**	**83.6%**
	32	Transport	18.5%	**68.6%**	**109.2%**
Other fields	33	Furniture, games	-3.8%	-37.0%	18.1%
	34	Other consumer goods	-16.8%	-25.5%	2.0%
	35	Civil engineering	-8.5%	**111.3%**	23.6%

Note: field "29 – Other special machines" includes weapons and ammunition (IPC codes: F41 and F42). These technical classes are entirely associated with the military sample according to the selection criterion.

Knowledge base of defence innovations

The backward citations of military patents were examined for the purpose of exploring the knowledge base of the defence innovations and of providing a preliminary aggregate evaluation of the presence of dual use cases. This analysis was carried out using a different approach from the method proposed for the identification of defence innovations. The identification of military patents for the years before 2002 only relies on the criterion based on IPC codes. This approach provides a consistent and robust condition that does not depend on the availability of patent texts and on the identification of defence companies, which would not have been possible since data on arms sales for in earlier years are not available.

Table 7 Composition of the knowledge base of military patents by technological fields as share of backward citations in 2002-08 and 2009-15.

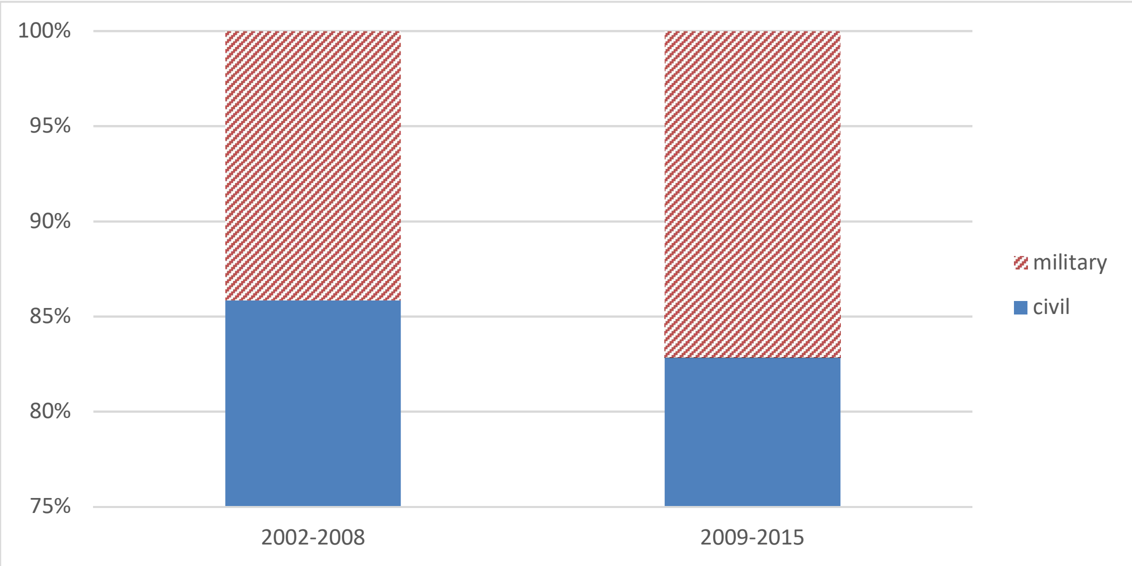
Sector	Field number	Field description	Perc. on tot. bwd.cit. 02-08	Perc. on tot. bwd.cit. 09-15	Delta in share of bwd.
Electrical engineering	01	Electrical machinery, apparatus, energy	8.5%	8.6%	
	02	Audio-visual technology	6.8%	7.9%	
	03	Telecommunications	10.5%	10.0%	
	04	Digital communication	6.4%	6.2%	
	05	Basic communication processes	3.1%	2.7%	
	06	Computer technology	11.2%	12.5%	
	07	IT methods for management	1.6%	1.6%	
	08	Semiconductors	5.1%	5.2%	
Instruments	09	Optics	7.5%	7.1%	
	10	Measurement	14.3%	15.4%	
	11	Analysis of biological materials	1.2%	0.9%	
	12	Control	5.5%	6.5%	
	13	Medical technology	4.6%	3.7%	
Chemistry	14	Organic fine chemistry	1.4%	1.2%	
	15	Biotechnology	1.3%	1.1%	
	16	Pharmaceuticals	1.2%	0.9%	
	17	Macromolecular chemistry, polymers	1.8%	1.4%	
	18	Food chemistry	0.3%	0.2%	
	19	Basic materials chemistry	3.0%	2.7%	
	20	Materials, metallurgy	3.2%	2.9%	
	21	Surface technology, coating	3.9%	4.1%	
	22	Micro-structural and nano-technology	0.7%	0.9%	
	23	Chemical engineering	3.8%	3.2%	
	24	Environmental technology	2.1%	1.8%	
Mechanical engineering	25	Handling	3.2%	3.1%	
	26	Machine tools	3.6%	3.9%	
	27	Engines, pumps, turbines	3.6%	4.7%	
	28	Textile and paper machines	2.1%	1.6%	
	29	Other special machines	17.4%	20.1%	
	30	Thermal processes and apparatus	1.6%	2.0%	
	31	Mechanical elements	4.6%	5.5%	
	32	Transport	11.0%	13.9%	
Other fields	33	Furniture, games	2.6%	2.8%	
	34	Other consumer goods	4.3%	4.1%	
	35	Civil engineering	5.5%	5.5%	

Note: field "29 – Other special machines" includes weapons and ammunition (IPC codes: F41 and F42). These technical classes are entirely associated with the military sample according to the selection criterion.

The composition of the knowledge base of military patents is identified by collecting the backward citations of the defence families. The distribution across the technological fields reflects the distribution of the innovation areas of the military patent families (previously shown in Table 5, column "Perc.on Military fam."). However, some technological fields represent a greater source of military technologies than the actual relative share of developed inventions. Table 7 reports the comparison between the relative share of backward citations in each technological field in the sample of military patents filed in 2002-08 and in 2009-15. Some technological areas increased their contribution as prior art cited by military innovations: "Transport", "Other special machines (incl. Weapon and Ammunition)", "Computer technology". Other fields reduced their contribution to the knowledge base of military innovations: "Medical technology", "Chemical engineering", "Telecommunications", and "Textile and paper machines".

The results suggest a potential trend of increasing specialisation as military patents are increasingly based on defence technological innovations. The evidence is confirmed when analysing the backward citations of military patents applying the identification criterion of defence technologies based on IPC codes (Figure 4). In the first period (2002-08) military innovations were developed from a knowledge base that is in a military technical field in 14.2% of the cases. In the most recent period (2009-15) the same share increased to 17.2%: defence innovations relied less on developments in civilian technological fields.

Figure 4 Change in the knowledge base (measured with backward citations) of military innovations: civilian vs military base as share of total backward citations in 2002-08 and 2009-15.



5 Dual use: identification and analysis

This section reports the results of the analyses of the identified dual use innovations according to the method proposed relying on citations. The definition used in this study identifies a dual use whenever a civilian invention is cited by a subsequent military innovation.

Table 8 shows the incidence of dual use cases with different reference pools: the whole sample of civilian inventions, of hybrid inventions, and the combined group containing both of them. Values for the sample limited to civilian innovations show that CC civilian use is 57.9% and CM dual use is 1.4%. Focusing on the subsample of hybrid inventions only, the dual use share is higher as expected from a group of firms marginally involved in military activities (3.4%)[11].

The data on the combined group of civilian and hybrid inventions indicates that 40.2% of the sample has not received a citation yet, 58.3% leads to CC civilian use, and finally CM dual use cases represent 1.5% of the total non-military patents. Since the number of hybrid patents is very small compared to the total number of civilian patents, the next analyses focus on the combined group. However, with the aim of highlighting the potential differences in dual use propensity, specific notes on the analysis at the company level are provided.

Table 8 Categories of forward citations for patent families in the civilian and hybrid categories, and combining both civilian and hybrid patents.

Reference sample	Category	% in ref. sample
Civilian patents	no citation received	40.6%
	At least one citation, no citation received by a military patent	57.9%
	At least one citation received by a military patent (PURE DUAL USE)	1.4%
	Total	**100.0%**
Hybrid patents	no citation received	31.4%
	At least one citation, no citation received by a military patent	65.2%
	At least one citation received by a military patent	3.4%
	Total	**100.0%**
Civilian and Hybrid Patents	no citation received	40.2%
	At least one citation, no citation received by a military patent	58.3%
	At least one citation received by a military patent (EXTENSIVE DUAL USE)	1.5%
	Total	**100.0%**

Table 9 reports several examples of CM dual use, i.e., civilian patents with at least one forward citation representing a subsequent military application.

[11] Please note that the sample of civilian patents is a residual group that also includes inventions that do not belong to companies as in the case of hybrid inventions: the presence of all the patents owned by individuals is a driver for the difference in the share of patents with no forward citations.

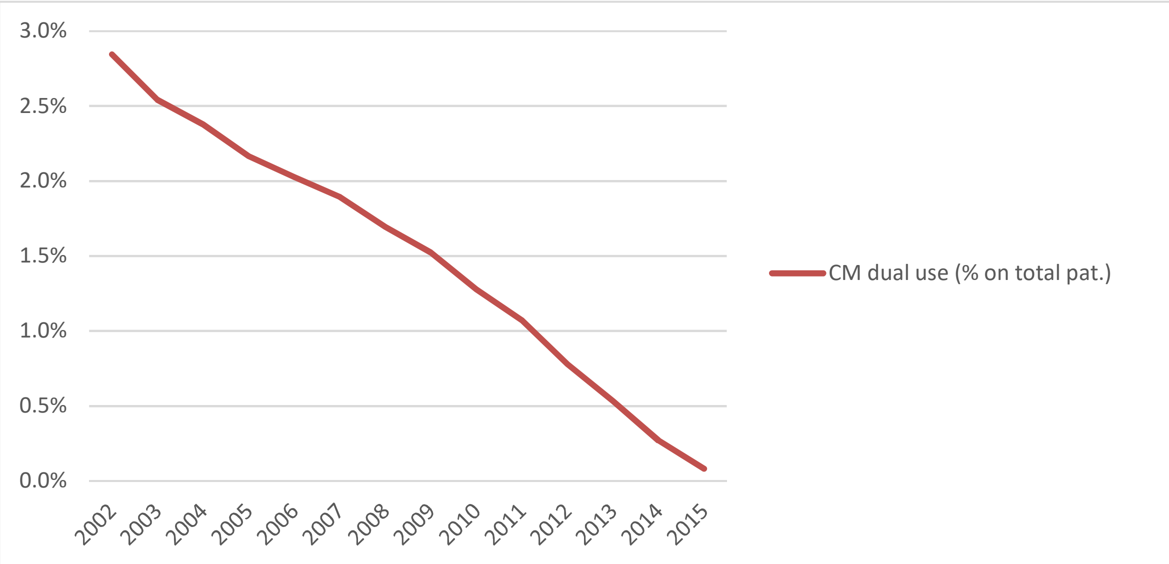
Table 9 Examples of dual use patent

Civilian patent Dual use	Title		Fwd. Cit. Military application	Title
US7219707B2	Enhanced hollow foam tyre structure	→	US9102198B2	Puncture-free bullet-proof tyre
US7408896B2	Method and system for providing mobile wireless access points	→	US7561881B2	Air based emergency monitor, multimode communication, control, and position finder system
US7848887B2	Making directional measurements using a rotating and non-rotating drilling apparatus	→	US9207053B2	Harmonic shuttered seeker
US201100184 93A1	Charger System and Method	→	US9958228B2	Telematics sensors and camera activation in connection with firearm activity

Trend

The following charts report the evolution of dual use cases. Figure 5 shows the yearly share of dual use cases (using the priority year of the source patent) compared to the total number of filed civilian inventions (continuous line). The chart shows a decreasing trend.

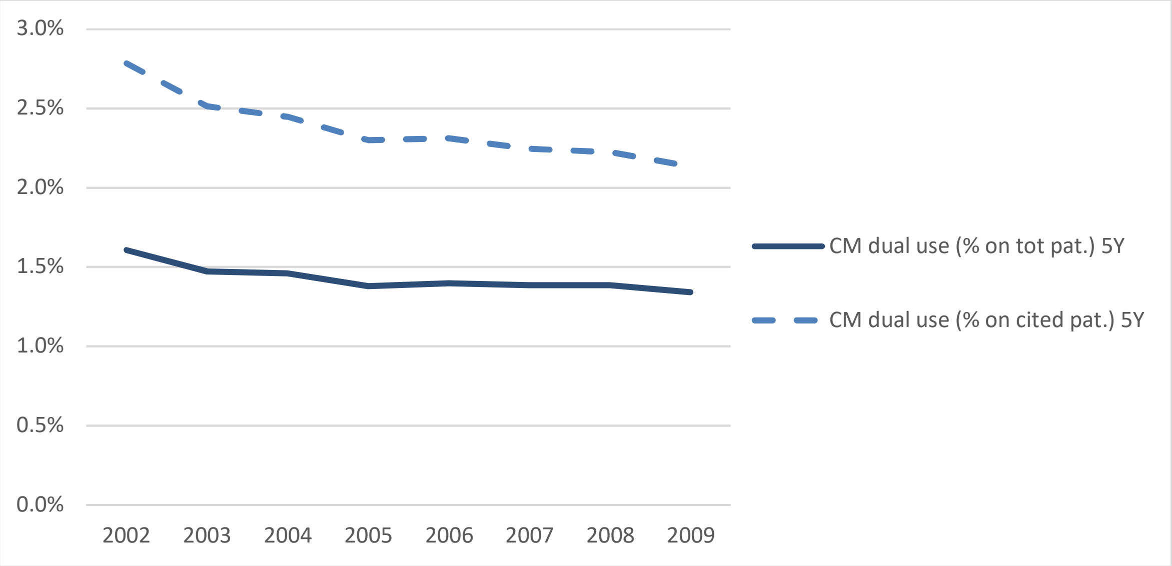
Figure 5 Trend of dual use share compared to the total sample of civilian patents (CM dual use).



However, this pattern is influenced by the definition of dual use proposed which relies on citations received. More recent patents have a smaller time window in which to receive citations than older ones. Since older patents are exposed to the "risk" of receiving a longer citation than recent ones, the analysis was replicated limiting the forward citations examined to a five-year window after the reference date of the cited invention. This approach makes it possible to compare yearly data on citations, and so data on the identification of dual use, with increased reliability from 2002 until around 2008/2009 (the tail of five years was excluded plus one or two years accumulated as delay between the priority and publication date).

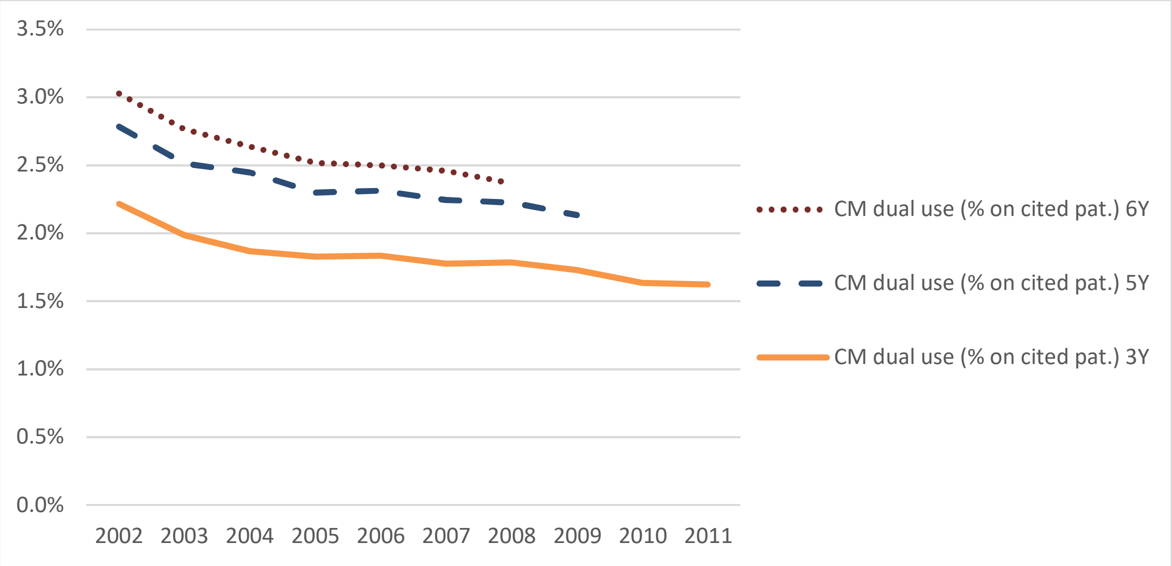
Figure 6 provides evidence that the reduction of dual use cases is not only induced by the identification method. In fact, the trend decreases slightly from 1.6% in 2002 to 1.3% in 2009 (continuous line) even when the share of dual use inventions is calculated conditional to a fixed time window for citations.

Figure 6 Trend of the share of CM dual use cases. The identification process only examined the citations in the five years after the priority date of the civilian focal patent. The continuous line represents the yearly share of the total number of civilian inventions. The dashed line represents the yearly share of the number of civilian inventions that received at least one citation (of any type).



Additional analyses were performed as robustness checks. The dual use share was calculated on the basis of a five-year citation window with respect to the subsample of civilian patents that received at least one citation (dashed line in Figure 6): the trend is decreasing. Alternative time windows were used for the inclusion of forward citations (three and six years) as shown in Figure 7. All of the results point to a decreasing trend[12].

Figure 7 Comparison of yearly trend based on different time windows for the inclusion of citations: three (continuous line), five (dashed line), and six years (dotted line). Shares are calculated on the number of patents with at least one citation.



[12] This last analysis also suggests that the time for civilian inventions to receive a citation from a military patent might on average be longer than receiving a subsequent civilian citation: dual use is on average 0.75% higher in the six-years window rather than when considering the three-years window.

It should be noted that the results are influenced by the different size of the pools of potentially citing patents. However, since the number of military patents is increasing while civilian inventions are quite steady (see previous Figure 3), an aggregate decreasing trend in CM dual use cases cannot be expected. Consequently, all the findings support the presence of a slightly decreasing trend on average. Potential explanations for this evidence could be:

- Reduced dependence: Several military companies focus on or have integrated civilian technologies and competences in their portfolio. These firms might have been involved in the acquisition of technologies or whole subsidiaries that were once mainly of a civilian nature. In other words, on average military firms do not rely so much on external civilian knowledge, consequently reducing the citations towards the previous civilian technological areas[13].
- Sector specificities: The two environments, "civilian" and "military" are less and less permeable even if there are differences between the technological sectors: some of them report a higher share of dual use cases in recent years (see section 0).
- Complexity: The military technological domain is getting slower in developing patented innovations based on civilian technologies: it takes more and more time to identify a spillover from civilian to military sectors due to technological complexity or specialization.

The result calls for further study to investigate the citation dynamics and their timing in order to disentangle the actual impact of the reasons proposed.

The comparison between the two directions of dual use cases, that is from civilian to military (CM dual use) and from military to civilian inventions (MC dual use) provides interesting results. It is important to note that the two samples of civilian and military patents are very different in size, with the former being 100 times larger than the latter. This holds true for their respective citing reference pools that determine the identification of dual use. On these grounds, the chances of identifying an MC dual use (the sample of potentially citing patents is the very large civilian one) are higher than for a CM case (the focal group of civilian patents can be cited by a potential relatively small sample of military inventions).

Direct comparison of the number of inventions with duality identified according to the two possible directions (CM or MC) is reported in Figure 8: the number of civilian inventions with subsequent military applications is four times the number of military patents with civilian applications. The comparison is quite steady with a slight change in recent years in favour of MC dual use cases. Potential reasons for this variation are:

- While the number of civilian inventions is quite constant in the time frame, military patents are increasing.
- Citations from civilian inventions to defence patents are faster on average than those from military to civilian patents.

[13] The overlap of the knowledge base of the military industry with the civil one increased: this translates into an increase in the identification of military inventions (see Figure 3) and in a small reduction on the identification of the spillover from one domain to the other.

Figure 8 Comparison of the number of MC and CM dual use cases identified when the identification is based on a five-year window of citations received.

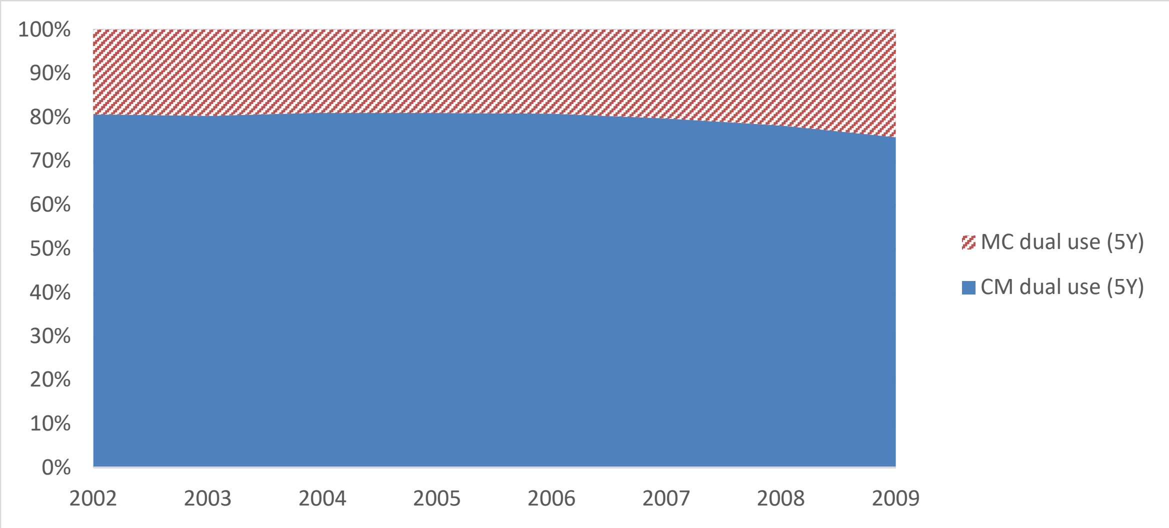
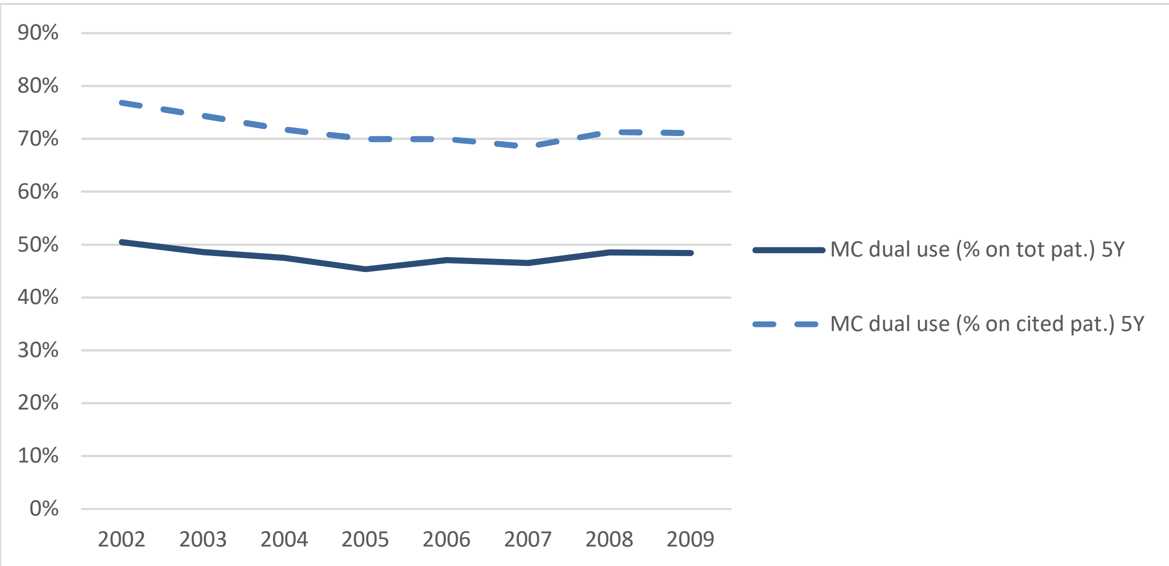


Figure 9 shows the yearly share of MC dual use cases, applying a five-year window for citations compared to the yearly number of military patents (continuous line) and of cited military patents (dashed line). Approximately 50% of the military inventions are cited by one or more civilian patent on a five-year window for forward citations. Although this result is very different from the small percentage found for the CM dual use incidence (approximately 1.5%, see previous Figure 6), the intrinsic large difference between the size of civilian and military samples (and correspondingly between their citing reference pools) is once again stressed.

Figure 9 Trend of the share of MC dual use cases. The identification process only examined the citations in the five years after the priority date of the focal military patent. The continuous line represents the yearly share of the total number of military inventions. The dashed line represents the yearly share of the number of military inventions that received at least one citation (of any type)



To improve the reliability of the direct comparison between the incidence of CM and MC duality, the size of the potential citing samples that determine the identification of dual use cases was incorporated in a single indicator. This indicator weights the relative share of dual use cases with the number of potentially citing patents (focusing on a five-year window coherently with the identification of dual use). The yearly average of this weighted dual use indicator calculated for CM is 3.6 times the value for MC[14]. This result suggests that when accounting for the size of the pool of citing patents, the relative presence of CM dual use is higher than MC.

Technological clusters

Table 10 shows the share of CM dual use innovations in each technological cluster identified according to the WIPO concordance table.

When considering the total number of CM dual use cases, the largest fields are "Computer technology" (33,102 inventions) and "Measurement" (24,808). Next after these fields, almost all of the technological clusters in the Electrical engineering area and the field "Transport" report the largest values of CM dual use.

Some differences emerge when considering the size of the clusters and focusing on the share of dual cases. Among the largest fields in terms of relative share of CM dual use cases compared to the total number of civilian inventions, it should be noted that:

- "Micro-structural and nano-technology", the smallest field by number of inventions developed, shows the highest incidence of dual applications starting from civilian inventions (5.2%);
- The area of "Electrical engineering" reports the largest number of CM dual use cases, in particular: "Basic communication processes" and "Telecommunications" (3.6%). This area favours the emergence of spillovers from civilian to military domains and vice-versa as identified in the previous study about civilian applications of defence inventions (Caviggioli et al., 2018)

The technological area where the presence of dual use is the smallest is "Chemistry" and in particular the fields "Pharmaceuticals" (0.8%), "Organic fine chemistry" (0.8%), and "Food chemistry" (0.3%).

[14] The weighted indicator of CM dual use (five-year citation window) is calculated yearly as the share of CM dual use on civilian (or hybrid) patents divided by the sum of military inventions developed in the subsequent five years. The average value is $0.480 * 10^{-6}$. The corresponding value for MC dual use is $0.135 * 10^{-6}$.

Table 10 Presence of dual use inventions across WIPO technological clusters. Both the total number of civilian and dual patent families are calculated on the total sample (2002-2015), and accordingly the share of dual use in each field. The change in the CM dual use share (last column) is calculated on the five-year window for forward citations as the difference between the share in 2006-09 and in 2002-05.

Sector	Field number	Field description	Civil pat. fam.	CM dual use pat. fam.	CM dual use (% in the field)	CM dual use > sample avg	Change of CM dual use %
Electrical engineering	01	Electrical machinery, apparatus, energy	1,024,776	18,169	1.8%	▶	-0.05%
	02	Audio-visual technology	809,693	18,195	2.2%	▶	0.07%
	03	Telecommunications	586,200	21,086	3.6%	▶	-0.49%
	04	Digital communication	532,585	17,782	3.3%	▶	-1.28%
	05	Basic communication processes	157,198	5,719	3.6%	▶	-0.76%
	06	Computer technology	1,178,955	33,102	2.8%	▶	-0.28%
	07	IT methods for management	281,855	4,547	1.6%	▶	-0.25%
	08	Semiconductors	680,031	11,886	1.7%	▶	-0.26%
Instruments	09	Optics	686,537	12,877	1.9%	▶	-0.18%
	10	Measurement	677,947	24,808	3.7%	▶	-0.38%
	11	Analysis of biological materials	110,180	2,145	1.9%	▶	-0.65%
	12	Control	360,792	13,024	3.6%	▶	-0.09%
	13	Medical technology	507,252	8,404	1.7%	▶	-0.42%
Chemistry	14	Organic fine chemistry	274,545	2,329	0.8%		-0.16%
	15	Biotechnology	216,360	2,708	1.3%		-0.22%
	16	Pharmaceuticals	274,123	2,322	0.8%		-0.31%
	17	Macromolecular chemistry, polymers	243,512	2,686	1.1%		-0.19%
	18	Food chemistry	205,789	524	0.3%		-0.06%
	19	Basic materials chemistry	326,559	4,197	1.3%		-0.26%
	20	Materials, metallurgy	287,851	5,149	1.8%	▶	-0.25%
	21	Surface technology, coating	356,089	8,180	2.3%	▶	-0.03%
	22	Micro-structural and nano-technology	47,916	2,565	5.4%	▶	-2.25%
	23	Chemical engineering	366,212	5,881	1.6%	▶	-0.37%
	24	Environmental technology	254,174	3,232	1.3%		-0.20%
Mechanical engineering	25	Handling	433,025	4,940	1.1%		0.06%
	26	Machine tools	363,844	5,698	1.6%	▶	0.19%
	27	Engines, pumps, turbines	402,695	7,235	1.8%	▶	0.25%
	28	Textile and paper machines	317,377	3,027	1.0%		-0.03%
	29	Other special machines	471,334	7,014	1.5%		0.00%
	30	Thermal processes and apparatus	272,518	3,172	1.2%		0.06%
	31	Mechanical elements	477,088	7,372	1.5%	▶	0.15%
	32	Transport	725,601	18,180	2.5%	▶	0.19%
Other fields	33	Furniture, games	490,618	4,557	0.9%		0.02%
	34	Other consumer goods	345,961	5,787	1.7%	▶	-0.05%
	35	Civil engineering	552,037	7,740	1.4%		0.03%

Note: field "29 – Other special machines" includes weapons and ammunition (IPC codes: F41 and F42). These technical classes are entirely associated with the military sample according to the selection criterion.

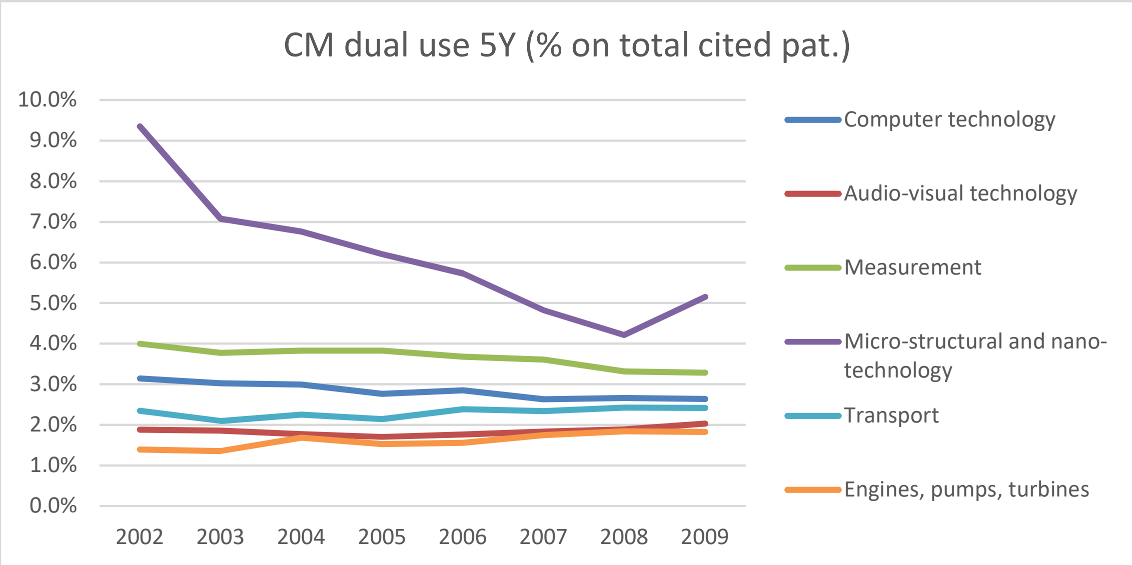
The last column of Table 10 reports the variation between the first (2002-05) and the second period (2006-09) for the CM dual use identified using the five-year window for forward citations. The largest military field (including weapons and ammunition), "Other special machines", saw no significant change in the share of CM dual use cases. Most of the fields report a negative variation: in particular, "Micro-structural and nano-technology" (with a net decrease of -2.25%)[15] and "Digital communication" (-1.28%).

However, some fields reported an increase in the relative presence of CM dual use and most of them are in the area of Mechanical Engineering: "Engines, pumps, turbines" (+0.25%), "Transport" (+0.19%), "Machine Tools" (+0.19%).

Figure 10 provides the detailed trend in the share of CM dual use cases (based on a five-year window of forward citations) in relevant technological fields.

[15] It is a very small area and small changes can translate into large percentage points.

Figure 10 Share of CM dual use cases (based on a five-year window of forward citations) as percentage of the sample of patents with at least one citation received in technological fields selected.



Geography

Table 11 reports the distribution of dual use across the priority POs and the total sample values. Offices proxy the source country of innovations and are ordered by number of dual use inventions. The largest PO is the USPTO with more than 80 thousand patent families that represent 58.7% of the total dual use inventions identified in the sample. The second PO is the JPO with a quarter of the dual use families of the USPTO (15.2%). Please note that the usual drafting style in Japan consists of filings with a lower number of claims, corresponding to a higher number of different families, which partly explains the total number of inventions from Japan.

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 (1.5%). Among the first 10 POs, the most prolific as origin of dual use patents is the USPTO with 4.7% of dual use cases out of the total civilian production. On the other hand, the JPO and the KIPO report a very low share of dual use cases, 0.6% and 0.5% respectively.

Table 11 Top 10 priority offices by number of dual use families (selected POs).

Priority office	Number of civil fam.	% on tot civ.	Number of dual use fam.	% on tot.dual	Perc. of dual use fam. on Office civil fam.
US	1,873,279	18.9%	88,407	58.7%	4.7%
Japan	3,845,213	38.9%	22,907	15.2%	0.6%
South Korea	1,731,299	17.5%	9,089	6.0%	0.5%
Germany	588,996	6.0%	7,162	4.8%	1.2%
EPO	211,448	2.1%	3,795	2.5%	1.8%
United Kingdom	236,180	2.4%	3,565	2.4%	1.5%
France	174,958	1.8%	3,358	2.2%	1.9%
PCT Filing - WIPO	147,284	1.5%	2,990	2.0%	2.0%
Russian Federation	339,006	3.4%	1,046	0.7%	0.3%
Italy	114,989	1.2%	567	0.4%	0.4%
Others	624,715	6.3%	7,768	5.2%	1.2%
Total	**9,887,367**	**100%**	**150,654**	**100%**	**1.5%**

Among the selected POs with at least 15 thousand civilian inventions in the interval 2002-15, the following POs were identified having a share of dual use families:

- higher than the global average (1.5%): USPTO (4.6% of total civilian innovations have a subsequent military application – pure dual use cases), France and Canada (1.9%), Sweden (1.6%), the UK (1.5%);
- between 1.0 and 1.5%: Germany and Finland (1.2%), India, Switzerland, and Austria (1.0%);
- less than 1.0%: the Netherlands (0.9%), Japan (0.6%), Italy and the Republic of Korea (0.5%), Spain (0.4%), Russian Federation (0.3%), Poland (0.0%).

The regions with the highest share of dual use cases are very similar to the results of the previous study (Caviggioli et al., 2018) which focused on the opposite direction of dual use, that is, from military innovations to civilian applications. The evidence suggests that on average the inventions developed in specific geographical areas have a "dual" nature more frequently than in other regions.

With the aim of providing a fine grained analysis of the geographical sources of dual use cases, the EPO patents in OECD REGPAT were analysed which makes the geolocalisation at the level of regions (NUTS2) Possible. Table 12 shows the first 20 regions by number of dual use inventions and the share of the regional portfolio of civilian patent output for each of them is reported.

Table 12 Top 20 geographical areas by count of civilian inventions with a subsequent dual use. Localisation based on the inventors' regions (NUTS2) for the sub-sample of EPO patents.

Rank	Inventors' region	Country	Dual use Families	Dual use (%)
1	California	US	7,177	7.5%
2	Southern-Kanto	JP	4,262	2.9%
3	New York	US	1,957	6.4%
4	Massachusetts	US	1,904	6.5%
5	Washington	US	1,753	9.9%
6	New Jersey	US	1,697	5.8%
7	Texas	US	1,668	6.3%
8	Kansai region	JP	1,536	2.6%
9	Capital Region	KR	1,362	2.7%
10	Pennsylvania	US	1,268	5.4%
11	Île-de-France	FR	1,220	2.8%
12	Ohio	US	1,146	5.6%
13	Illinois	US	1,100	5.4%
14	Oberbayern	DE	1,058	2.8%
15	Minnesota	US	1,048	6.0%
16	Michigan	US	986	6.3%
17	Toukai	JP	965	2.4%
18	Ontario	CA	959	5.6%
19	South East England	UK	947	4.6%
20	Stuttgart	DE	880	2.3%

As expected, several regions from the US rank among the top 20 by number of CM dual use cases identified. The rest of the positions are occupied by regions where the number of patent filings is high due to the presence of large innovative companies: Southern-Kanto, Kansai and Toukai in Japan, the Capital region of South Korea, and some European areas (Île-de-France, Oberbayern and Stuttgart in Germany, South East England).

Figure 11 and Figure 12 map the presence of CM dual use as a share of the total civilian innovations in Europe and the USA: the darker colour stands for a higher incidence of civilian inventions that are subsequently cited by military ones. The analysis is limited to the areas with regions having at least 500 civilian patent families.

Figure 11 Geographical origins of civilian inventions with subsequent military application in Europe (regions with at least 500 patent families). Localisation based on the inventors' regions (NUTS2) for the sub-sample of EPO patents. Range from minimum to maximum share of dual use inventions of total civilian innovations.

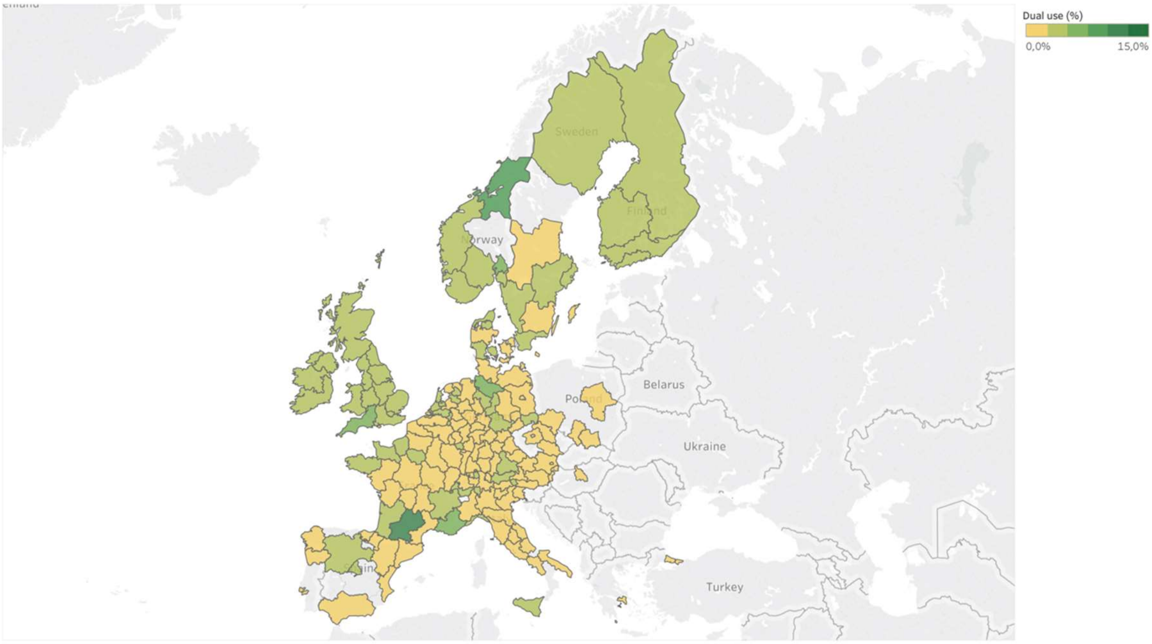
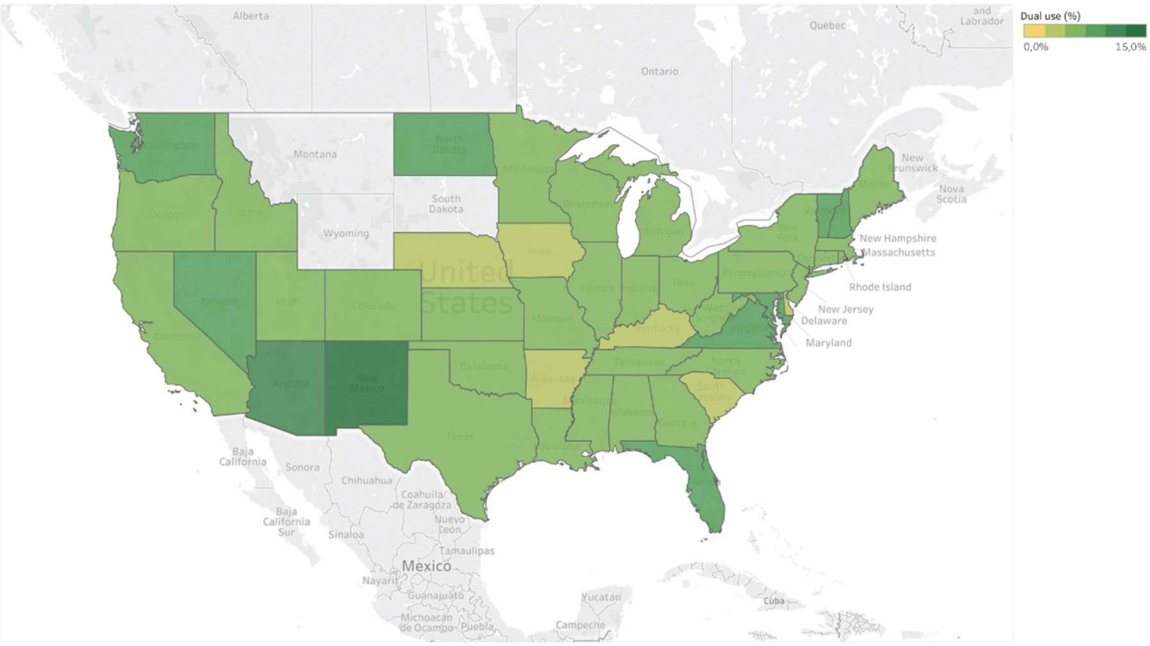


Figure 12 Geographical origins of civilian inventions with subsequent military application in the USA (regions with at least 500 patent families). Localisation based on the inventors' regions (NUTS2) for the sub-sample of EPO patents. Range from minimum to maximum share of dual use inventions of total civilian innovations.



Dual use as geographical knowledge spillover from civilian innovations to defence technologies

Comparing the first priority offices of the cited and citing patent families in the analysis of the citation network reveals that the former represents the origin of the invention, the latter the geographical area where the subsequent innovation was developed. 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 the localisation of a subsequent implementation. This approach is useful in estimating the size of domestic follow-ups with respect to cross-border spillover.

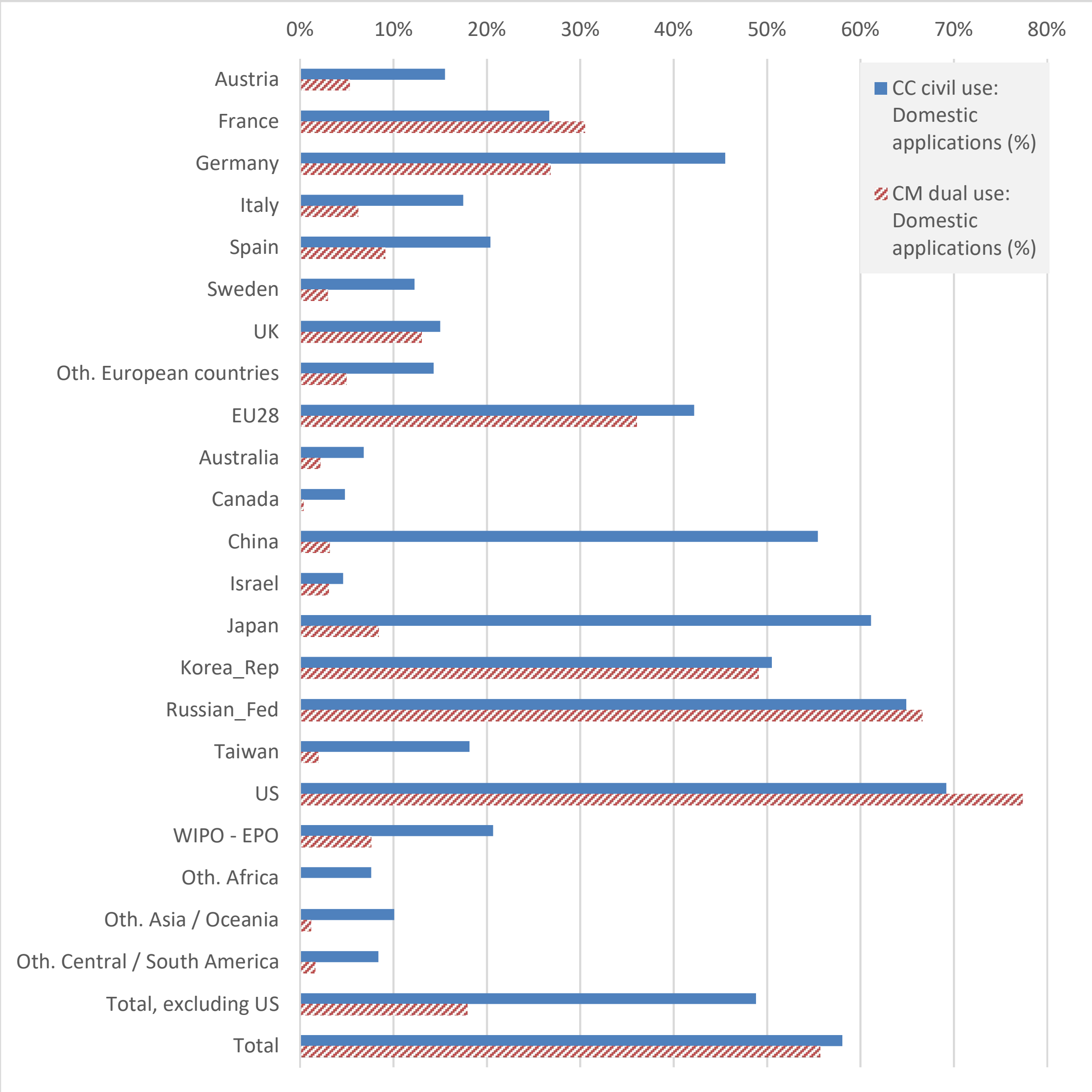
It should be noted that a single invention can be cited by several families associated with various priority countries. This data structure leads to multiple destination countries: the sum of the flows is higher than the total number of starting inventions and then the calculation of shares can be different from the previous (in particular, for dual use cases that are defined as a characteristic of the source invention but is determined by the citation pattern). Furthermore, it is worth remembering that at this stage, the analysis does not control for the general propensity of receiving citations, and particularly domestic citations, of the patents issued by each patent authority. Language barriers and access to shared patenting procedures might favour citation flows in certain areas (e.g. US globally, German citations to Austrian patents, etc.) and limit the internationality 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.

Figure 13 compares the shares of domestic flows (i.e., the incidence of inventions developed in a specific geographical area and cited by a subsequent application invented in the same territory) for the sample of non-dual innovations (CC civilian use) and of CM dual use cases. Data reveals heterogeneity across countries.

Domestic CC civilian use is very common for countries like the USA, the Russian Federation, Japan, and South Korea. On the contrary, the civilian innovations developed in countries like Australia, Canada, or Israel find subsequent non-dual application more frequently outside the national borders, and in most cases in the USA (see Figure 14 and Figure 15 in the appendix for further details on the citation flows concerning the most relevant POs).

The innovations developed in Europe (EU28) are the basis for further inventions developed in the same area in 42% and in the USA in 26% of cases. For the USA, the share of domestic CC civilian use is 69% while the spillover to the EU28 area amounts to approximately 6%.

Figure 13 Incidence of domestic applications based on citation flows between cited and citing priority countries: values for CC civilian use and CM dual use (dashed red bars), details by origin main offices (on the left axis).



* Notes: Priority offices are a proxy for the geographical origin of inventions. China and Taiwan were not included in the starting selected sample of publication authorities. However, the identification process led to the inclusion of patent families with a first priority country in geographical areas different from the starting sample (e.g. China and Taiwan). Data for these POs are consequently underestimated.

Values for the subsample of dual use innovations, i.e., the domestic CM dual use (dashed red bars in Figure 13) are different for some countries. The same data is also reported in Table 13 (column (1) and (2)). The comparison between the incidence of the domestic flow of dual and non-dual cases makes it possible to highlight the fact that in most of the countries the domestic spillover for dual is lower than domestic CC civilian use. This finding suggests that a military application of a civilian innovation is relatively more frequent outside the country's borders. The USA, France, and the Russian Federation show a different pattern where the share of domestic CM dual spillover is higher than the domestic CC civilian use.

The share of domestic CM dual use in the EU28 area is 36%, smaller than the corresponding non-dual value (42%).

In order to examine the domestic spillover effect from civilian to military further, the last column of Table 13 combines the share of domestic CM dual use cases in each region (column (2)) with the local presence of dual use cases (column (3)). The value in the last column of Table 13 provides a rough regional multiplier that estimates the relationship between the total civilian research output at regional level and the corresponding spillover to the military domain in the same area. The estimated multiplier is a lower bound since some of the military technologies that could have been patented actually are not due to the requirements of secrecy.

Rather than the actual value of the multiplier, it is interesting to highlight the heterogeneity across countries. The USA represents a neat outlier, being the most likely to transform the civilian research output into subsequent domestic military applications. When considering the geographical area of the EU28, the multiplier shows a relatively high presence of local civilian innovations becoming dual inside the EU28 borders. This result is only partly driven by the intra-national phenomenon (as for France and Germany). The values for the other larger member countries (e.g. Austria, Italy, Spain, and Sweden) are lower than the value of the aggregate EU28: it suggests the presence of a cross-border effect, having a civilian invention developed in one of the member state, later used by a different member country in a military application. On the contrary, Canada is the least likely to turn internally developed civilian innovations into new local military inventions.

Table 13 Share of civilian inventions cited by a civilian one with the same priority PO (domestic civilian-to-civilian flow), share of civilian inventions cited by a military one (dual use), share of civilian inventions cited by a military one with the same priority PO (domestic civilian-to-military flow), and combined effect representing the spillover of civilian innovations on the domestic military research output (local spillover). Values by country of origin.

Origin Office	Civil-to-civil flows: share of domestic (%) (1)	Dual use flows, share of domestic (%) (2)	Presence of dual use (%) (3)	Local spillover of civil-to-military (2) * (3)
Austria	15.5%	5.3%	1.0%	0.05
France	26.7%	30.5%	1.9%	0.59
Germany	45.5%	26.8%	1.2%	0.33
Italy	17.5%	6.2%	0.5%	0.03
Spain	20.4%	9.1%	0.4%	0.03
Sweden	12.3%	3.0%	1.6%	0.05
UK	15.0%	13.0%	1.5%	0.20
Oth. European countries	14.3%	5.0%	0.7%	0.03
EU28	42.2%	36.1%	1.2%	0.43
Australia	6.8%	2.1%	4.8%	0.10
Canada	4.8%	0.4%	1.9%	0.01
China	55.5%	3.2%	1.2%	0.04
Israel	4.6%	3.1%	2.7%	0.08
Japan	61.2%	8.4%	0.6%	0.05
Korea Rep	50.5%	49.1%	0.5%	0.26
Russian Fed	64.9%	66.7%	0.3%	0.21
Taiwan	18.2%	2.0%	1.8%	0.04
US	69.2%	77.4%	4.7%	3.65
WIPO - EPO	20.7%	7.6%	1.9%	0.14
Oth. Africa	7.6%	0.0%	2.5%	0.00
Oth. Asia / Oceania	10.1%	1.2%	1.1%	0.01
Oth. Central / South America	8.4%	1.6%	1.7%	0.03
Total, excluding US	**48.8%**	**17.9%**	**0.8%**	**0.14**
Total	**58.1%**	**55.7%**	**1.5%**	**0.85**

Companies and dual use

The main assignees in the following tables are listed according to different criteria: the largest owners of civilian innovations that are cited by military inventions (Table 14); the assignees with the largest number of military inventions based on civilian inventions according to the definition of dual use proposed (Table 14). Company name standardisation is based on the OECD HAN database included in PATSTAT 2018.

Table 14 lists the top 20 assignees by number of civilian families that have been cited by a subsequent military application (dual use families). Among these companies, some show a higher share of dual use compared to the company's total invention portfolio: Motorola (10.5%) and Boeing (9.6%), the latter being one of the firms included in the SIPRI database but with revenues from arms sales below the 50% threshold (the same as for HP).

Table 14 Top 20 innovators by number of CM dual use.

Rank	Assignee	Country	Portfolio (tot fam.)	Dual use fam. (#)	Dual us fam. (%)	Type of comp.
1	IBM CORP	US	58438	2036	3.5%	Civil
2	SAMSUNG ELECTRONICS	KR	110746	1643	1.5%	Civil
3	MICROSOFT CORP	US	22415	1238	5.5%	Civil
4	SONY CORP	JP	51741	885	1.7%	Civil
5	THE BOEING CO	US	8104	778	9.6%	Hybrid
6	HITACHI LTD	JP	48079	724	1.5%	Civil
7	INTEL CORP	US	14885	713	4.8%	Civil
8	FUJITSU LTD	JP	42347	688	1.6%	Civil
9	TOYOTA MOTOR CORP	JP	93044	632	0.7%	Civil
10	NOKIA CORP	FI	7411	534	7.2%	Civil
11	ROBERT BOSCH GMBH	DE	44278	531	1.2%	Civil
12	CANON INC	JP	102556	529	0.5%	Civil
13	ELECT & TELECOM RES INST (ETRI)	KR	16613	492	3.0%	Civil
14	HONDA MOTOR CO	JP	38137	472	1.2%	Civil
15	HEWLETT PACKARD	US	18845	461	2.4%	Hybrid
16	MATSUSHITA ELECTRIC IND CO	JP	60584	450	0.7%	Civil
17	QUALCOMM INC	US	8522	429	5.0%	Civil
18	MOTOROLA INC	US	4052	425	10.5%	Civil
19	DENSO CORP	JP	47088	417	0.9%	Civil
20	LG ELECTRONICS INC.	KR	73117	407	0.6%	Civil

Table 15 lists the top 20 patent owners responsible for transforming previous civilian inventions into defence innovations (CM dual use "converters"). In other words, the table shows those companies and defence agencies that introduced the largest amounts of civilian inventions into the military perimeter. The focus in this list is on the military companies that developed innovations from civilian inventions (two hybrid companies rank among the top 20). The company responsible for the largest share of dual use cases is Raytheon (7.2%)[16].

[16] Note that the civil inventions cited by Raytheon, or any other CM dual use converter, could also be cited by other military companies. Consequently, it cannot be stated that without Raytheon those inventions would not become dual.

Table 15 Top 20 patent owners by number of military applications of previous civilian inventions: the table shows the companies responsible for the subsequent dual application of the largest values of civilian inventions (top 20 CM dual converters).

Rank	Assignee	Ctry	Number of previous civil fam. cited by one or more of the assignee's military patents (activated CM dual use)	% on tot. dual use cases	Type of comp.
1	RAYTHEON	US	10,852	7.2%	Military
2	THALES	FR	8,141	5.4%	Military
3	LOCKHEED MARTIN	US	7,476	5.0%	Military
4	HARRIS	US	5,338	3.5%	Military
5	US NAVY	US	4,263	2.8%	Military
6	BAE	GB	4,208	2.8%	Military
7	NORTHROP GRUMMAN	US	3,605	2.4%	Military
8	AGENCY FOR DEFENSE DEVELOPMENT	KR	2,754	1.8%	Military
9	SAMSUNG TECHWIN	KR	2,196	1.5%	Hybrid
10	AIRBUS DEFENCE & SPACE	EU	1,817	1.2%	Military
11	US ARMY	US	1,706	1.1%	Military
12	SANDIA	US	1,673	1.1%	Military
13	SAGEM DEFENSE SECURITE	FR	1,433	1.0%	Military
14	BELL HELICOPTER TEXTRON	US	1,199	0.8%	Military
15	SAAB AB	SE	1,142	0.8%	Military
16	SIKORSKY AIRCRAFT	US	1,116	0.7%	Military
17	EADS	EU	1,036	0.7%	Hybrid
18	EXELIS	US	965	0.6%	Military
19	QINETIQ	UK	965	0.6%	Military
20	HANWHA TECHWIN	KR	861	0.6%	Military

Table 16 provides additional information on the military companies that rarely generate dual applications. The table reports the number of military inventions owned by each assignee that cite previous civilian patents and the relative share of the total portfolio. As expected, the two hybrid companies that do not have all their patents identified as military but only those with defence-related IPC or keywords show a small share of "dual-activating" patents. Interestingly, there are differences across the military assignees. A group of assignees that also includes some of the US and South Korean defence agencies reports value approximately 50% or below (among the companies: BAE, Northrop Grumman, and Qinetiq). Three companies show high shares of patents that are based on civilian inventions in their portfolio: Exelis (92%), Bell Helicopter Textron (84%), and Harris (81%).

Table 16 Number of military inventions of the top 20 CM dual converters that are responsible for the generation of CM dual use cases and their share in the total company portfolio.

Rank	Assignee	Ctry	Number of military fam. citing a previous civil fam. (#)	Perc on tot. portfolio	Type of comp.
1	RAYTHEON	US	10,852	7.2%	Military
2	THALES	FR	8,141	5.4%	Military
3	LOCKHEED MARTIN	US	7,476	5.0%	Military
4	HARRIS	US	5,338	3.5%	Military
5	US NAVY	US	4,263	2.8%	Military
6	BAE	GB	4,208	2.8%	Military
7	NORTHROP GRUMMAN	US	3,605	2.4%	Military
8	AGENCY FOR DEFENSE DEVELOPMENT	KR	2,754	1.8%	Military
9	SAMSUNG TECHWIN	KR	2,196	1.5%	Hybrid
10	AIRBUS DEFENCE & SPACE	EU	1,817	1.2%	Military
11	US ARMY	US	1,706	1.1%	Military
12	SANDIA	US	1,673	1.1%	Military
13	SAGEM DEFENSE SECURITE	FR	1,433	1.0%	Military
14	BELL HELICOPTER TEXTRON	US	1,199	0.8%	Military
15	SAAB AB	SE	1,142	0.8%	Military
16	SIKORSKY AIRCRAFT	US	1,116	0.7%	Military
17	EADS	EU	1,036	0.7%	Hybrid
18	EXELIS	US	965	0.6%	Military
19	QINETIQ	UK	965	0.6%	Military
20	HANWHA TECHWIN	KR	861	0.6%	Military

6 Conclusions

The study proposes a method that relies on patent data to identify defence innovations and dual use cases. Extending the previous companion study (Caviggioli et al., 2018) and the empirical approaches available in the scientific literature, several search approaches were used to classify military patents: assignee names of defence firms in the SIPRI database and the CERTIDER Register, military-specific IPC codes, and the presence of military keywords in patent text fields. The patent citation network makes it possible to identify dual use cases as both civilian inventions stemming from defence ones, and in particular in the opposite direction, that is, from civilian inventions to further military applications.

The method proposed analysed 10 million patent families from selected patent offices in the years 2002-2015. In this sample, 220,858 defence patents corresponding to 85,034 families (0.9% of the whole sample) were identified. Patents belonging to “hybrid” companies (i.e., with arms sales below 50% of total revenues) represent 4.8% of the total sample.

The number of civilian patent families slightly decreased in the years examined while hybrid and military inventions increased by 4% and 30% respectively (the sample does not include Chinese patents).

Concerning military innovations, the geographical distribution and the technological composition across the WIPO sectors are consistent with the previous results (Caviggioli et al., 2018). The USA is the largest source of defence patented innovations and alone accounts for a share equal to the sum of South Korea, the Russian Federation, France, Germany, Japan, and the UK (approximately 43%). The combined share of the largest European countries by number of defence innovations, that is, France, Germany, UK, Italy, Poland, Spain, Sweden, Austria, and Finland, amounts to 20% of all the military inventions.

The analyses of the technological distribution of civilian, hybrid, and military samples reveal the presence of similarities such as the relevance of “Computer technology”, and specificities: hybrid patents have a similar distribution to the civilian sample but, due to the identification method, they show a relevant presence in “Engines, pumps, turbines” and “Transport”; as expected the defence innovations concentrate in “Other special machines” (42.3%), which includes “Weapons and ammunition”. The presence of military innovations in “Computer Technology” is non-negligible (9.8%) but is also lower than the civilian (11.7%) and hybrid sample (16.8%).

The largest increase in civilian technological cluster (approximately 50%) occurs in smaller fields like “Micro-structural and nano-technology”, “IT methods for management”, and “Digital communication”. Within the hybrid innovations, the highest growth rates are found for the fields in the Mechanical Engineering area and “Civilian engineering” (above 50% increase). The presence of military patent families particularly increased in the areas of Electrical and Mechanical Engineering.

Focusing on the knowledge base of the military inventions identified reveals a shift from the technological base covered by fields like “Chemical engineering”, “Telecommunications”, and “Textile and paper machines” to a more intense use of inventions not only in “Other special machines (incl. Weapon and Ammunition)” but also in “Transport” and “Computer technology”. The results suggest a potential trend of increasing specialization as military patents are increasingly based on defence technological innovations with the significant exception of the use of “Computer technology” as a source of new developments. The comparison between the first period (2002-08) and the more recent (2009-15) shows an increase in reliance on the military knowledge base, that is, from 14.2% to 17.2%, rather than on the larger pool of civilian technological fields.

This study operationalised dual use in both the case from a civilian to a military application (CM dual use) and when considering the opposite direction (MC dual use). The focus was on the latter in the report of Caviggioli et al. (2018) while this study provided extensive analyses on the former and a comparison between the two. The presence of CM dual inventions is 1.4% of the total civilian sample. This percentage in the hybrid sample increases to 3.4% as expected from a group of firms partly involved in military activities. CM dual use cases in the aggregate civilian and hybrid sample represent 1.5% of the total non-military patents. Several analyses were performed to address the issues concerning the truncation of recently filed patents and the very large difference in size between the potential citing pools of patents determining the identification of dual use. All of the analyses suggest the presence of a slightly decreasing trend in CM dual use (from 1.6% in 2002 to 1.3% in 2009).

Some preliminary potential drivers are advanced to explain the result: i) the defence companies absorbed civilian technologies and competences; ii) at the aggregate level the two domains, “civilian” and “military” are less and less permeable but some technological sectors have revealed a higher share of dual use cases in recent years (especially in the area of Mechanical Engineering); iii) it takes more and more time to identify a spillover from civilian to military sectors due to technological complexity or specialization.

The comparison between the two directions of dual use cases, that is, from civilian to military (CM dual use) and from military to civilian inventions (MC dual use) provides interesting results. In absolute numbers, the CM dual inventions are four times the MCs. The share CM dual use has in the civilian sample is 1.5% while the MC dual use share of the corresponding military sample is approximately 50%. This huge difference seems to be driven by the intrinsically large difference between the size of civilian and military samples (as denominators and as citing reference pools). In fact, when weighting the number of potential citing patents, the relative presence of CM dual use is 3.6 times higher than MC.

Among the technological fields where CM dual use seems to occur the most, it should be noted that the smallest field by number of inventions developed, "Micro-structural and nano-technology" (5.2%), but this field also shows the highest decrease in the period examined(-2.25%). The whole area of "Electrical engineering" (in particular "Basic communication processes" and "Telecommunications", 3.6% each) appears to favour the emergence of spillovers from civilian to military domains and vice-versa as identified in the previous study about civilian applications of defence inventions (Caviggioli et al., 2018).

The area of "Mechanical engineering" reports an increase in the relative presence of CM dual use (in particular: "Engines, pumps, turbines" (+0.25%), "Transport" (+0.19%), and "Machine Tools" (+0.19%)).

The regions with the highest share of CM dual use cases are very similar to those found for MC cases (Caviggioli et al., 2018). The evidence suggests that the inventions developed in specific geographical areas on average have a "dual" nature more frequently than in other regions. The largest PO is the USPTO with more than 80 thousand patent families that represent 58.7% of the total dual use inventions identified in the sample; the share of CM dual use on total civilian inventions is 4.7% in the USA.

The analysis of the patent citation network led to the generation of a matrix of knowledge flows for the purpose of highlighting the presence and the relative share of spillover within and across countries. The results suggest a significant heterogeneity in the share of domestic knowledge flows. The comparison between the incidence of the domestic flow of dual and non-dual cases makes it possible to highlight the fact that the domestic spillover for dual is lower than for non-dual in most of the countries. This finding suggests that a military application of a civilian innovation is relatively more frequent outside the borders of a country. This is different in the USA, France, and the Russian Federation, where the share of domestic CM dual spillover is higher than the domestic CC civilian use. The share of domestic CM dual use in the EU28 area is 36%, smaller than the corresponding non-dual value (42%).

An index to allow cross-country comparison was calculated which accounts for the relative presence of dual use and combines the share of domestic CM dual use cases in each region with the local presence of dual use cases. Rather than the actual value of the multiplier, it is interesting to highlight the heterogeneity across countries. The USA represents a neat outlier, being the most likely to transform the civilian research output into subsequent domestic military applications. When considering the geographical area of the EU28, the multiplier shows a relatively high presence of local civilian innovations that become dual inside the EU28 borders. This result is only partly driven by the intra-national phenomenon (such as for France and Germany). The values for the other larger member countries (e.g., Austria, Italy, Spain, and Sweden) are lower than the value of the aggregate EU28: it suggests the presence of a cross-border effect, having a civilian invention developed in one of the member state and then used by a different member country in a military application.

The companies with the largest number of civilian inventions with a subsequent military application are IBM, Samsung, and Microsoft with CM dual use ranging between 1.5 to 5.5% of their portfolios. Motorola (10.5%) and Boeing (9.6%) show a relatively higher share in their patent portfolio, with the latter being one of the firms that are included in the SIPRI database but with revenues from arms sales below the 50% threshold (it is the same for HP).

The top 20 CM dual use "converters", those responsible for transforming previous civilian inventions into defence innovations, include two US and one South-Korean hybrid government agency companies. The company responsible for the largest share of dual use cases is Raytheon (6.8% of the total sample of dual cases). With respect to the share of patents responsible for dual use out of the total portfolio, Exelis (92%), Bell Helicopter Textron (84%), and Harris (81%) show the highest values. On the contrary, a group of assignees that includes the US and South Korean defence agencies reports a portfolio share of approximately 50% or below (e.g. BAE, Northrop Grumman, and Qinetiq).

The present study is not exempt from limitations which can be addressed in future research. In particular, future studies could improve the identification of dual use cases starting by using the method proposed. 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 if they consider macro level data for the input factors (e.g. national expense in the defence sector) and data for the characteristics of the patent systems (e.g. language and cooperation treaties facilitating citation flows).

References

Acosta, M., Coronado, D., & Marín, R. (2011). *Potential dual-use of military technology: does citing patents shed light on this process?* Defence and Peace Economics, 22(3), 335-349.

Acosta, M., Coronado, D., Ferrandiz, E., Marín, R., & Moreno, J. (2017). *Patents and dual-use technology: an empirical study of the world's largest defence companies* Defence and Peace Economics, 1-19

Alic, A. (1992). Beyond spinoff: Military and Commercial Technologies in a changing world. Harvard Business Press.

Avadikyan, A., & Cohendet, P. (2009). Between market forces and knowledge based motives: the governance of defence innovation in the UK. The Journal of Technology Transfer, 34(5), 490-504.

Avadikyan, A., Cohendet, P., & Dupouët, O. (2005). A study of military innovation diffusion based on two case studies. Innovation policy in a knowledge-based economy, 161-190.

Bellais, R., and Guichard, R. (2006). Defense Innovation, Technology Transfers and Public Policy. Defence and Peace Economics 17 (3): 273–86.

Bukkvoll, T., Malmlöf, T., & Makienko, K. (2017). The defence industry as a locomotive for technological renewal in Russia: are the conditions in place?. Post-Communist Economies, 29(2), 232-249.

Caviggioli F., De Marco A., Scellato G. (2018). Assessing the innovation capability of EU companies in developing dual use technologies, EUR 29481 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/032120

Enger, S. G. (2013). Dual-Use Technology and Defence–Civilian Spillovers: Evidence from the Norwegian Defence Industry (Master's thesis). Available at: https://www.duo.uio.no/bitstream/handle/10852/35932/Engerx-xMaster.pdf.

European Commission (2017a). Reflection Paper On The Future Of European Defence. COM(2017) 315 of 7 June 2017. Available at https://ec.europa.eu/commission/sites/beta-political/files/reflection-paper-defence_en.pdf.

European Commission (2017b). White Paper On The Future Of Europe. COM(2017)2025 of 1 March 2017. Available at https://ec.europa.eu/commission/sites/beta-political/files/white_paper_on_the_future_of_europe_en.pdf.

García-Estévez, J., & Trujillo-Baute, E. (2014). Drivers of R&D investment in the defence industry: evidence from Spain. Defence and Peace Economics, 25(1), 39-49.

Kepe, M., Black, J., Melling, J., & Plumridge, J. (2018). Exploring Europe's Capability Requirements for 2035 and Beyond. RAND Europe, June 2018, prepared for the European Defence Agency (EDA) in response to the invitation to tender No.16.CPS.OP.186.

Kim, D. H., Lee, B. K., & Sohn, S. Y. (2016). Quantifying technology–industry spillover effects based on patent citation network analysis of unmanned aerial vehicle (UAV). Technological Forecasting and Social Change, 105, 140-157.

Kuzyk, M., Grebenyuk, A., Kakaeva, E., Manchenko, E., & Dovgiy, V. (2017). What Impedes Universities from Creating Dual-Purpose Technologies?. Foresight and STI Governance, 11(4), 84-95.

Lazaric, N., Mérindol, V., & Rochhia, S. (2011). Changes in the French defence innovation system: New roles and capabilities for the Government Agency for Defence. Industry and innovation, 18(5), 509-530.

Lee, B. K., & Sohn, S. Y. (2017). Exploring the effect of dual use on the value of military technology patents based on the renewal decision. Scientometrics, 112(3), 1203-1227.

Maclin, H. M., Hauser, A. A., & Rakowski, W. (1994). Dual-use ensures technology cross over. LEADING EDGE(EVENDALE OH), 30-31.

Martí Sempere, C. (2018). What Is Known About Defence Research And Development Spill-Overs?. Defence and Peace Economics, 29(3), 225-246.

Molas-Gallart, J. (1997). Which way to go? Defence technology and the diversity of 'dual-use' technology transfer. Research Policy, 26(3), 367-385.

Morales-Ramos, E. (2002). Defence R&D expenditure: The crowding-out hypothesis. Defence and Peace Economics, 13(5), 365-383.

Mowery, D. C. 2010. "Chapter 29 – Military R&D and Innovation. "In Handbook of the Economics of Innovation. Vol. 2, edited by B. H. Hall and N. Rosenberg, 1219–1256. North-Holland. http://www.sciencedirect.com/science/article/pii/S0169721810020137.

Schmid, J. (2017). The Diffusion of Military Technology. Defence and Peace Economics, 1-19.

Oltmann, S. (2015). Dual use research: Investigation across multiple science disciplines. Science and engineering ethics, 21(2), 327-341.

Smith, B. G. (1994). Civilian and military space in Europe: An industrial perspective. Space Policy, 10(2), 91-94.

Te Kulve, H., & Smit, W. A. (2003). Civilian–military co-operation strategies in developing new technologies. Research policy, 32(6), 955-970.

Watkins, T. A. (1990). Beyond guns and butter: Managing dual-use technologies. Technovation, 10(6), 389-406.

List of abbreviations and definitions

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

Annexes

Keywords for the identification of military patents

Table 17 List of concepts and keywords searched in patent text fields. Decision on inclusions/exclusion as selection criterion for the defence patent database

Keyword	Searched text fields	Decision based on 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 gluing
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 turret
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 artefacts

Technological fields based on the WIPO concordance table

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

Table 18 WIPO concordance table

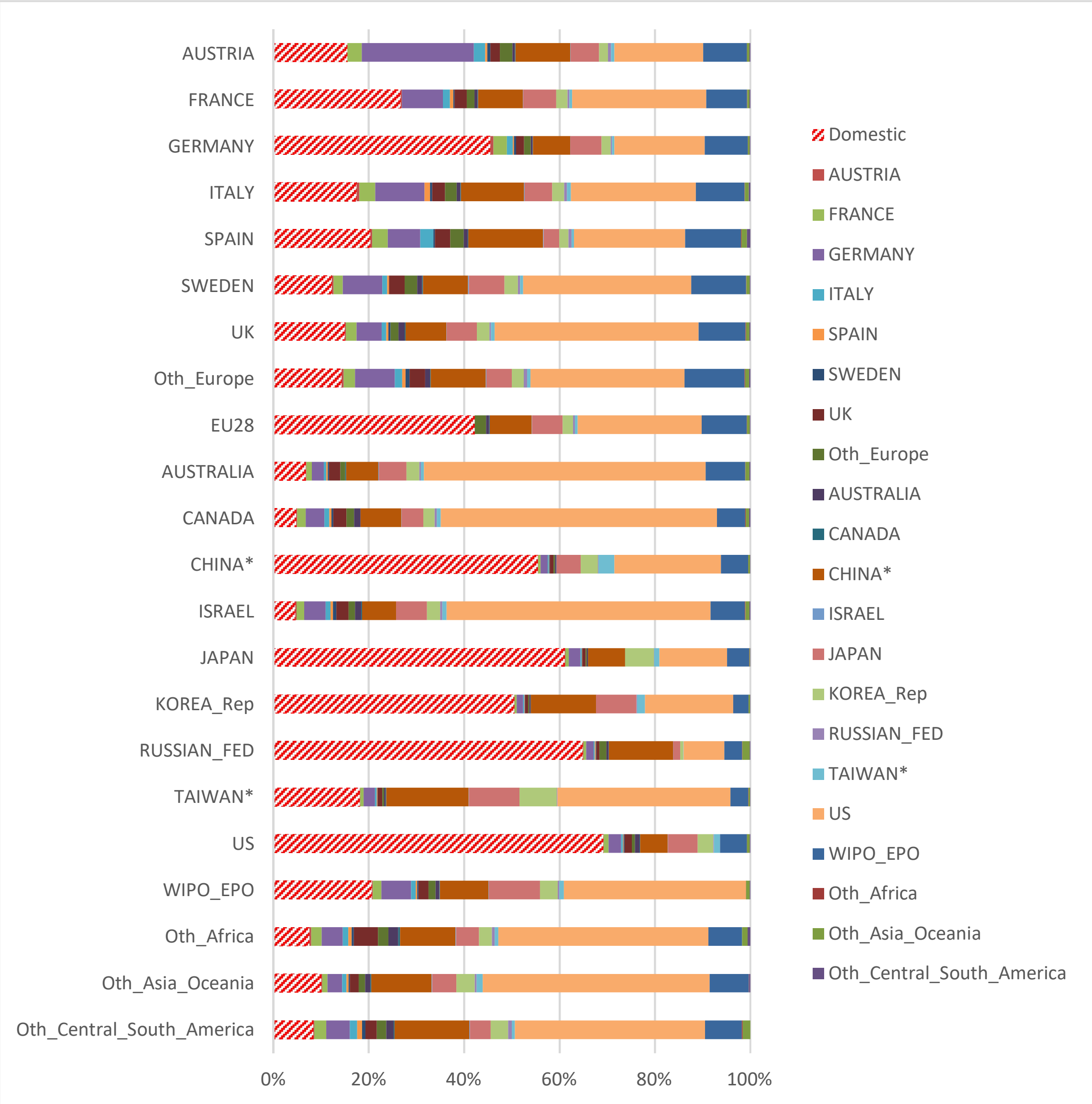
Sector	Field	List of IPC codes
Electrical engineering	Electrical machinery, apparatus, energy	F21H, F21K, F21L, F21S, F21V, F21W, F21Y, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H02B, H02G, H02H, H02J, H02K, H02M, H02N, H02P, H02S, H05B, H05C, H05F, H99Z
Electrical engineering	Audio-visual technology	G09F, G09G, G11B, H04N0003, H04N0005, H04N0007, H04N0009, H04N0011, H04N0013, H04N0015, H04N0017, H04N0019, H04N0101, H04R, H04S, H05K

Sector	Field	List of IPC codes
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
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

Sector	Field	List of IPC codes
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	Civilian 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

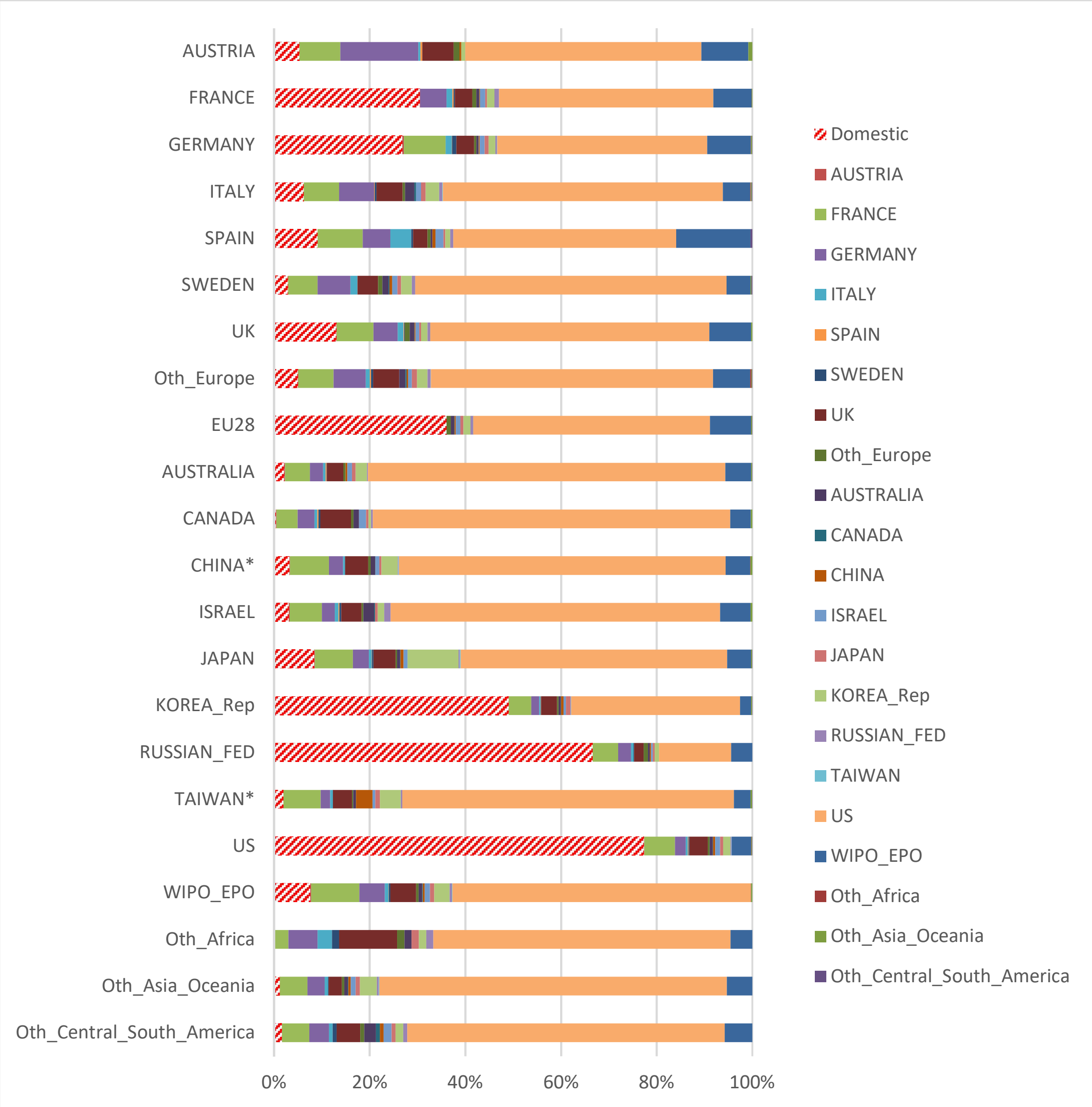
Details of geographical flows of civilian and dual applications of civilian inventions

Figure 14 Citation flows of CC civilian use (civilian innovations that have been cited by civilian inventions – sample of non-dual cases), details by origin main offices (on the left axis). Domestic flow are shown in dashed red, other destination geographical areas are shown in different colours.



* Notes: Priority offices are a proxy for the geographical origin of inventions. China and Taiwan were not included in the starting selection sample based on the publication authorities. However, the identification process led to the inclusion of patent families with a first priority country in geographical areas different from the starting sample (e.g. China and Taiwan). Data for these POs are consequently underestimated.

Figure 15 Citation flows of CM dual use cases (civilian innovations that have been cited by a military invention), details by origin main offices (on the left axis). Domestic flow are shown in dashed red, other destination geographical areas are shown in different colours.



* Notes: Priority offices are a proxy for the geographical origin of inventions. China and Taiwan were not included in the starting selection sample based on the publication authorities. However, the identification process led to the inclusion of patent families with a first priority country in geographical areas different from the starting sample (e.g. China and Taiwan). Data for these POs are consequently underestimated.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: https://europa.eu/european-union/contact_en

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: https://europa.eu/european-union/contact_en

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: https://europa.eu/european-union/index_en

EU publications

You can download or order free and priced EU publications from EU Bookshop at: https://publications.europa.eu/en/publications. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see https://europa.eu/european-union/contact_en).

KJ-02-20-246-EN-N

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub

ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

Publications Office of the European Union

doi:10.2760/78635

ISBN 978-92-76-17893-4