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**Abstract**

Drawing upon 106,181 patent applications by the world's largest defense firms and 241,571 patent citations (2002-2011), this paper has two main objectives. The first is to explore the factors affecting the production of mixed patents (those with potential dual applications in both military and civilian spheres). The second is to identify the causes of the use of military knowledge for civilian inventions (spin off) and the use of civilian knowledge in military patented technologies (spin in). Our calculations show highly significant coefficients for the variables capturing the "military technological capability" and the size of the company in explaining the production of mixed technologies. The spin off process is affected by the military technological capability, the size of the firm and the location. The spin in mechanism is explained by the military technological capability and the location of the firm, while the size of the company is not relevant.

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## Introduction

The main purpose of this paper is to contribute to the discussion on the relationship between military and civilian technologies in two ways. First, it explores the factors affecting the capacity of the leading defense firms to generate dual-use technological products. Second, it identifies the causes prompting their ability to incorporate military technological knowledge into civilian inventions (*spin off*) and the inflow of civilian knowledge in military patented technology (*spin in*) [1].

The extent to which military knowledge is used to support civilian technologies offers new insights into the application of military knowledge in civilian markets. The underlying relevance of the analysis of the *spin off* process relies on the fact that many advanced technologies that were initially designed with offensive or defensive purposes might be available for civilian and commercial purposes. Similarly, the application of civilian knowledge to develop military inventions provides some clues about the role of the *spin in* process. Our final goal is to provide new perspectives on the relationship between military and civilian technologies that might contribute to the debate on new dual-use policies and provide a better organization of the innovation systems.

Our data consist of both economic information on the leading defense firms provided by the Stockholm International Peace Research Institute (SIPRI) and their production of patented technology from the PATSTAT database. We first analyze the production of mixed technologies. In a second step, we identify the inflows of military knowledge into civilian technologies (*spin off*) and civilian knowledge into military technology (*spin in*) by using backward patent citations.

The paper contributes to the literature in three ways. First, it analyzes the extent to which civilian and military technologies that are related to each other could provide new clues on innovation policies. As stated by Mowery (2012), despite the fact that defense-related R&D investments have influenced innovation in the broader civilian economy of several OECD nations, the scope and nature of this influence remains uncertain. Second, this is one of the few quantitative studies that offer a new perspective from the output side (patents) to identify technologies with dual potential applications. The use of patents will enable us to clarify what firms are involved in dual-use technologies and to what extent. Third, to the best of our knowledge, only Acosta, Coronado, and Marín (2011) and Acosta, Coronado, Marín, and Prats (2013) offer a glimpse into the military-civilian flows of technology from a quantitative view.

The remainder of this paper is organized as follows. In Section 2, we discuss the literature relevant to this paper. In Section 3, we explain the methodology based on the information contained in patents to measure the production and inflows of technological knowledge. In Section 4, we present the data. In Section 5, we address the production of mixed technologies. In Section 6, we identify the inflows of knowledge from military into civilian technologies. Conclusions and some policy implications are drawn at the end of the paper.

**Background Literature**

The main reason to analyze the production and flows of knowledge between military industry and civilian sectors is the opportunities and social benefits from a better integration of the civilian-military technological spheres. One of the potential ways in which military technology can provide potential benefits to civilian sectors is linked to the concept of dual-use technology (e.g. Acosta et al., 2011; Alic et al., 1992; Cowan & Foray, 1995; Kulve & Smit, 2003; Lu, Kweh, Nourani, & Huang, 2016; Molas-Gallart, 1997; Williams-Jones et al., 2014). The term “dual-use” was originally coined in discussions about technology transfers between civilian and military applications. It is associated with the idea that civilian and military research and technology can go together to maximize their usage in a win-win scenario (Rath, Ischi, & Perkins, 2014). Dual-use can be understood in two ways: military technology used for civilian innovation (*spin off*) or, conversely, civilian technology applied to military inventions (*spin in*).

Despite the fact that there is some evidence on the adoption of civilian technology for military purposes (Avadikyan, Cohendet, & Dupouët, 2005; Cowan & Foray, 1995; Mowery, 2010; Reppy, 2006), the main focus has been on how military innovations spill over to civilian innovations (Acosta et al., 2011). As stated by Lu et al. (2016), by incorporating military technologies into private industries, countries transfer military innovations or inventions into civilian life, thereby increasing individual incomes and also helping to upgrade the technology in private industries.

In this paper we rely on the general idea stemming from evolutionary economics that technological capabilities are the main factor encouraging firm innovation. The concept of technological capability –defined as the knowledge and skills that firms continuously acquire, adapt, and improve (e.g. Cerulli, 2014)– is also connected with the term "absorptive capacity" as one of the main *core-competences* highlighted in the resource based view approach. Cohen and Levinthal (1990) define "absorptive capacity" as the firm's capability to recognize the value of new, external information, assimilate it, and apply it to commercial ends. However, the defense industry has its own particularities. As we explain in the data section, defense firms compete in civilian and military technological markets. They produce different types of technological outputs in accordance with their civilian or military technological capabilities.

Avadikyan et al. (2005) address the causes affecting the *spin off* process of military technology and identify four enabling factors: 1) the technological variety, in the sense of technologies stemming from different sectors; 2) *spin-in* or two-way diffusion since it brings the defense and the civilian sectors closer; 3) military functionality close to the civil sector needs; and 4) the tendency in defense projects to subcontract work to SMEs, which are often engaged in civilian activities. Mowery (2010, p. 1231) finds that US defense firms with the highest proportions of revenues derived from military sales tend to specialize in military markets, reducing their motivations for civilian applications. Brzoska (2006) suggests that the differences in the objectives of technological innovation between military and civilian sectors are also more likely as one nears the development of weapons. This is confirmed by the results of Acosta et al. (2011). In contrast, dual-use technologies will be more likely for firms with civilian and military revenues. To the best of our knowledge, only Acosta et al. (2011, 2013) have contributed to the topic by analyzing patent citations to identify the flow of knowledge from military to civilian technologies.

## Methodology

### Patents and Patent Citations as Indicators of Production and Flows of Military Knowledge

Patents have been one of the most widely used sources of data among researchers for the evaluation of R&D outputs (Griliches, 1990; Jaffe & Trajtenberg, 2002). In the defense industry, the use of patents can provide information on the innovative patterns of defense related firms and their evolution across time (Molas-Gallart, 1999).

To identify the different types of patented technologies produced by the largest defense firms (details about such firms are explained in the following section), we gathered all types of patented technologies. Then, we classified each type of technology into one of three categories (military, civilian and mixed technology) by using the International Patent Classification (IPC). The main military IPC codes are sectors F41 (weapons) and F42 (ammunition, blasting) along with other IPC codes related to military technology. A discussion about this classification can be found in Acosta el al. (2013).

Following the IPC Guide (point 131), where it is stressed that "*patent documents should not be classified as a single entity, but all different inventive things",* we define military/defensive, civilian and mixed patented technologies as follows.

- Military patents. A patent is classified as "military" if it contains only military IPC codes.
- Mixed patents. A patent is classified as "mixed" if it includes one or more military IPC codes, and at least one nonmilitary IPC code (any of the other codes included in the IPC). Mixed patents are then proxies for *dual-use* technologies.
- Civilian patents. A patent is classified as "civilian" if the "inventive things" in the patent are not classified under any of the military IPC codes.

Once the patents are identified and classified, we built upon the main ideas from the literature on patent citations (e.g. Acosta & Coronado, 2003; Breschi & Lissoni, 2004; Jaffe & de Rassenfosse, 2017; Jaffe, Fogarty, & Banks, 1998; Jaffe & Trajtenberg, 2002) to analyze the inflows of military knowledge into civilian technology (and civilian into military).

**Models and Variables**

We specify and estimate three main count models that will allow for identifying the explanatory factors affecting the production of dual-use technologies and the *spin off/spin in* processes. The next paragraphs provide some details about the variables and the specification.

**Dependent variables.** We consider three dependent variables that will be explained using separate models. The first one is the number of mixed patent applications by each firm to proxy for dual-use technologies. The second variable captures the *spin off* process by using the number of military patent citations in civilian patents. The third variable uses the number of civilian patent citations in military patents to describe the *spin in* process.

**Independent variables.** Our main independent variables are two indicators that account for the civilian and military technological capabilities of a firm, respectively. The first indicator captures the “civilian” technological capability to produce new technologies and is defined as the number of civilian patents divided by the civilian sales of the company (total sales minus arms sales). The second indicator captures the “military” technological capability to produce new technologies and is defined as the number of military patents divided by the arms sales of the company (this indicator expresses the number of military patents for each million $ of arm sales). The model includes additional variables to control for the size of the company (the log number of employees); the military commercial profile of the firm, which is defined as the percentage of arms sales over the total sales of the company (for example, a ratio of 0.5 means that half of the revenues stem from arms sales, and the other half from civilian products); and the location, which is captured by a dummy variable that takes the value of 1 for companies from the US and 0 otherwise.

Because we are dealing with a count variable as the dependent variable, the nature of the data suggests the formulation and estimation of a count model (Poisson or negative binomial). The default parameterization of the Poisson model, in which the conditional mean of observation i depends on a number of explanatory factors, is the exponential mean: $\mu_i = exp(x_j'\beta), i = 1, \dots,$. This model may be estimated using the maximum likelihood (ML). The standard procedure for obtaining the estimators is the Newton–Raphson iterative method, which is computed using Stata 14. Convergence is ensured because the logarithmic likelihood function is globally concave.

However, one restriction of the Poisson model is that it assumes that the mean and variance of the dependent variable are equal, and so, this framework breaks down when the data are overdispersed. Unlike the Poisson model, which is fully characterized by its mean, the negative binomial is a function of two parameters: its mean $\mu$ and another coefficient $\alpha$ that captures overdispersion. Then, the mean is still $\mu$, but its conditional variance is $(1+\alpha\mu)$. If the dispersion parameter is zero, it is appropriate to fit a Poisson regression model (see Cameron & Trivedi, 1986; 1998, for a detailed discussion).

**Data**

This section describes our data and sources of information. The construction of our dataset followed several steps. First, we selected the biggest defense firms that have available data, which is published annually by the SIPRI. It provides information about the total sales, armament sales, total employment and profits of each company. The database covers the period from 2000-2014 and includes the firms with the highest volumes of armament sales. [2] Although the SIPRI includes information until 2014, we have ruled out the years from 2012-2014 because the patent data for the latest years are incomplete. The years 2000 and 2001 were also discarded due to the lack of data. Another limitation in the SIPRI data set is that not all firms have information for all the years. To provide a clear picture that enables comparisons, we have averaged the data for each firm by using all available years (obtaining one observation for each variable and firm). This also reduces the number of outliers.

Second, using the list of the top defense firms obtained in step 1, we retrieved the number of patent applications from the European Patent Office between 2002 and 2011. The patent information was taken from the Worldwide Patent Statistical Database (PATSTAT, Spring 2014 edition), which includes data from the European Patent Office (EPO). To be efficient in the search, we built on the K.U. algorithm.[3] Table 1 presents some microeconomic characteristics of the firms classified by countries. Note that the SIPRI includes the top 100 companies in its database, but our final sample consists of 71 firms, which are those with available microeconomic data.

[Table 1 near here]

Third, we classified the 106,181 patents obtained in the previous step into the three categories according to their IPC codes and our classification that was explained above (civilian patents –only with civilian IPC codes; military patents –only with military IPC codes; and mixed patents –containing both civilian and military IPC codes).

Finally, in order to identify the intensity of the *spin off* (flows of knowledge from military into civilian technologies) and the *spin in* (flows of knowledge from civilian into military technologies), we gathered all the citations (backward citations) included in the patents obtained in step 3 and classified these citations according to the IPC codes. This information results in 241,529 backward patent citations, which were classified as military, civilian or mixed according to the IPC codes.

**The Production of Mixed Patents by Top Defense Firms**

In this section, we address the first objective of the paper, which is to explore the factors affecting the production of mixed patents applications by the leading defense firms. We are particularly interested in analyzing why some firms are more prone to produce what we defined above as mixed technologies or those technologies with both civilian and military potential applications. The section is split into two parts. We first present some figures on the types of patent applications by the main defense companies, and, second, we estimate a negative binomial regression to identify the effects of the main explanatory factors.

**Technological Outputs: Civilian, Military and Mixed Patents**

Table 2 depicts the firms with greater production of civilian patents, and Table 3 lists the firms in order of their number of mixed patents. The last three columns of each table present the distribution according to the type of patent. These tables show the following.

- Civilian patents are the bulk of the production of technology by top defense firms: 93.7% of all patent applications by top defense firms are civilian. Only five firms account for more than 50% percent of all patents in the sample (General Electric, Honeywell, EADS/AIRBUS, Hewlett Packard and NEC).
- Military patents account for 2.3% of all patents. These patents are even more concentrated than civilian patents in a few firms, such as Rheinmetall, Raytheon, Nexter, Kraus-Maffei, Diehl and Saab.
- Mixed patents are a small fraction of the bulk of the patent applications by the top defense firms. On average, only 1% of the patents owned by these firms are mixed.

[Table 2 near here]

[Table 3 near here]

**The Effect of the Firm Technological Capability on the Production of Mixed Patents**

The main question addressed in this section is to what extent is the production of mixed patents related to the technological profile of the firm? In other words, is the civilian technological capability what affects the production of mixed technologies, or is the military technological capability what triggers the production of mixed patents?

To analyze the influence of the civilian and technological capabilities of the firm on the production of mixed patents, we have specified and estimated a negative binomial model in which the dependent variable is the production of mixed patents by the leading defense firms, and the explanatory variables represent the technological capability of the firm along with some control variables (as described in a previous section). We also present the Poisson model with the robust standard error only for comparison.

Table 4 presents the descriptive statistics, and Table 5 shows the pairwise correlation matrix between each of the variables. The correlation matrices were checked to address the potential multicollinearity problems, which could interfere with determining the precise effects of the predictor variables. As indicated in Table 5, the correlations among explanatory variables are low. To further evaluate the presence of collinearity issues, we calculated the variance inflation factors (VIFs) to rule out any multicollinearity concern (the VIFs are presented at the bottom of each model).

[Table 4 near here]

[Table 5 near here]

Table 6 presents the estimation results. As explained, our baseline specification assumed that the dependent variable followed a Poisson distribution, but the presence of overdispersion led us to consider negative binomial models as the preferred model (the significance of the overdispersion parameter *alpha* also confirms that the data do not follow a Poisson distribution).

[Table 6 near here]

The coefficient of the variable "military technological capability" is highly significant, while the coefficient of "civilian technological capability" is not statistically significant. The model confirms that the production of mixed patents is closely related to the military technological capability of the firm, while the civilian technological capability does not seem to play any role.

On the other hand, the positive and highly significant coefficient of the size of the company suggests that the larger the company is, the more mixed patents are produced by the firm. However, we found only weak evidence supporting the roles of the "military commercial profile" and location; their coefficients are significant, but only at the 10% significance level. Table 6 includes some additional values for a diagnostic check (values at the bottom). The chi2 test suggests that the model is statistically significant, and the "LR test of alpha=0" shows that the negative binomial model would be preferred to the Poisson. The adjusted R2 is not high in the negative binomial model, but this is not a cause for concern, given that our main purpose is testing the significance of coefficients and not making predictions. The table also presents the VIFs for identifying multicollinearity problems, which are ruled out (the average VIF is 1.34 and the maximum is 1.5, which are well below the standard cut-off point of 10).

**Inflows of Knowledge from Military into Civilian Technologies (*Spin off*) and from Civilian into Military Patents (*Spin in*)**

The purpose of this section is to analyze whether defense firms support their production of civilian/military-patented technologies using military/civilian previous knowledge and to what extent. The study of these *spin off* /*spin in* processes sheds some light on the relationship between military and civilian technologies. The section is divided into two parts. First, we take a descriptive look at the data, and second, we estimate a negative binomial model to determine whether the firm's technological profile and other variables affect the *spin off/spin in* phenomenon.

**Military Citations into Civilian Patents, and Civilian Citation into Military Patents: A Window on the Spin off/Spin in Processes**

Table 7 shows a rough picture regarding the type of knowledge used by defense firms. On average, the majority of citations are civilian (96.27%) and only a small fraction (2.75%) were citations to patents with a military component. Note from the third column, which accounts for the average number of citations in each patent, that a greater number of citations does not imply a higher intensity in the use of knowledge.

[Table 7 near here]

When an invention is civilian (because all its IPC codes are civilian) but its citations to other patents includes military knowledge (patents in which at least one of its IPC codes is classified as military or mixed), then we can assume that there has been a *spin off* process in which military knowledge has been useful for supporting a particular civilian technology. Likewise, we assume that there has been a *spin in* when a civilian patent is cited by a military patent.

Table 8 lists the top defense firms arranged according to the number of military or mixed citations. Column 2 shows the sum of the military and mixed citations in all patent applications by firms, which is an indicator capturing the use of military knowledge that supports all the patents (civilian and military) owned by the firm. Column 3 presents the number of military and mixed citations in the civilian patents. These citations represent the military knowledge that supports civilian inventions, and it can be interpreted as an indicator of the *spin off* process. Column 4 is just the ratio between column 2 and column 3, and it captures the extent to which military knowledge is used in civilian patents. The right part of the table follows the same structure to capture the *spin in* process.

[Table 8 near here]

From this table, two relevant conclusions can be drawn. First, the *spin off* process is much more intense that the *spin in* process (11.1% of all military and mixed citations made by defense firms support civilian inventions, while only 0.16% of all civilian citations are included as previous knowledge in military patents). Second, the variability of the *spin off/spin in* process is very high among firms, which means that apparently there is not a clear pattern that might explain the differences in the use of military knowledge to support civilian inventions or vice versa. We explore this issue in the following section.

**Factors Affecting the Spin off and the Spin in Processes**

As shown in the previous section, firms do not rely much on military knowledge to support civilian patents or on civilian knowledge to produce military patents. We also found a great variability among firms in the use of such knowledge. To explore some of the factors determining the use of military knowledge in civilian patents (*spin off*) and the use of civilian knowledge in military patents (*spin in*), we have estimated several negative binomial regressions in which our dependent variables are the numbers of military and mixed citations in civilian patents (*spin off*) and the number of civilian citations in military patents (*spin in*), respectively. Our independent variables are the same as those used in our previous model to explain the production of patents. We use the same variables for two reasons. First, it is alleged that the civilian and military technological capabilities of a firm would affect not only the production of new technologies but also the use of new knowledge as well. This happens because firms with greater technological potential have more capacity to scan, assimilate and apply new available knowledge than other firms with low technological potential. Since we are dealing with the use of military knowledge in civilian patents (or vice versa), we have included both the military technological capability and civilian technological capability. As in our previous model, we also control for the size of the company, its military commercial profile, and the location of the company. Second, the use of the same variables allows us to compare the extent to which the effects of the explanatory factors differently affect the production of mixed patents and the *spin off/spin* in processes.

The estimation results are shown in Table 9. The models explaining the *spin off/spin in* processes show that the military technological capability of the firm is highly significant, which suggests that the intensity of the *spin off/spin in* processes is positively related to the ability of the firm to deal with the knowledge involved in military patents. Note that the civilian technological capability is not relevant in any model.

[Table 9 near here]

With respect to the variable “military commercial profile”, we found only weak evidence of its effect on the *spin off* process (with a significant coefficient at the 10% level), and it is independent of the *spin in* mechanism. Regarding the other variables, the coefficient of the location is statistically significant in explaining both the *spin off* and the *spin in*, while the size is only relevant in the *spin off*.

Table 9 includes additional information for diagnostic checks. In particular, the chi2 test suggests that the models are statistically significant, and the “LR test of alpha=0” shows that the negative binomial models are preferred compared to the Poisson. The adjusted R2 is not high in the negative binomial models, but again, this is not a problem because our objective is to test the relevance of some explanatory factors. The VIFs also indicate that there are not multicollinearity issues.

The lack of causality between the civilian technological capability and the *spin off* process suggests that some firms can have a great ability to develop civilian technologies, but they do not count on the skill to process military knowledge in order to use it for their civilian inventions and generate a *spin off* mechanism. Similarly, although a firm might know how to use civilian knowledge efficiently, it can have difficulties in applying this knowledge to military inventions and producing *spin in* because they mainly generate civilian patents, and they do not specialize in producing military patents.

The insignificant coefficient of the "military commercial profile" (% of arms sales over total sales) to explain the *spin in* mechanism is probably due to the fact that this is a variable capturing the sales profile of the company, which might be independent from the technological ability of the firm to scan, absorb and implement previous military knowledge to produce civilian patents.

**Conclusions**

This paper uses patent information to explore two relevant issues for connecting the military and the civilian technological spheres. First, we addressed the capacity of defense firms to produce mixed patents, which is a proxy for accounting for dual-use technological products. Second, we examined both the firms' ability to support civilian inventions by using previous military knowledge in their patents (*spin off*) and the firms' capacity to use civilian knowledge in their military patents (*spin in*). We drew on a newly constructed data set covering all patent applications by the biggest defense firms from 2002 to 2011. By using a methodology that includes the estimation of negative binomial regressions, our main findings can be summarized as follows.

- The defense industry is composed of firms whose patent activity is not just focused on producing military knowledge. In particular, the biggest defense firms are capable of generating mixed technologies with potential applications to both military and civilian spheres.
- To identify the role of the firm's technological ability on the production of mixed patents, we have estimated a negative binomial regression. The results show that what truly matters for generating mixed technologies is

the "military technological capability", while the "civilian technological capability" is not relevant. The "size" of the company is highly significant. However, we have found only weak evidence regarding the role of the "military commercial profile" and the "location", whose coefficients are significant but only at the 10% level.

- Using the number of military patent citations included into civilian patents (as a proxy for *spin off*) showed that the intensity of the *spin off* process can be quantified in approximately 11,1%. The *spin in* process (quantified as the number of civilian patent citations included into military patents) is considerably less intense, as only 0.16% of all civilian citations by the top defense firms are included as previous knowledge in military patents.
- Our negative binomial regressions show that, on the one hand, the *spin off* process depends on the military technological capability, the size of the firm and the location. The military commercial profile is also relevant in explaining the number of military citations in civilian patents (*spin off*), but only at the 10% level. On the other hand, the *spin in* process is explained by the military technological capability and the location of the firm, while the size is not relevant.

With respect to the balance, the overall picture seems to be that defense firms devote considerable efforts to developing civilian inventions, while the production of mixed technologies is a very small part of their patent activity. The *spin off* process could be described as intense since more than eleven percent of the military knowledge that firms use in all their patents goes to support civilian inventions, while the *spin in* process is considerably less relevant. The variable "military technological capability," which quantifies the firm's potential to create new military patented inventions per unit of military revenue, is the main factor affecting the production of mixed technologies and the *spin off/spin in* processes.

These results contribute to the debate on the relationship between the military and civilian technological spheres. Dual-use policies require the design of a wide range of interventions focused on connecting military and civilian technologies and fostering innovation projects with military and civilian components. The discussion about the relationship between military and civilian technologies has given rise to a wide range of policies aimed at fostering shared innovation projects at the intersection between military and civilian networks (Merindol & Versailles, 2010; Stowsky, 2004) or at encouraging new forms of organizing the innovation (Guichard, 2005; James, 2009). Developments about *spin-in, spin off* or shared innovation represent a set of incentives aimed at creating positive externalities between civilian and military markets (Cowan & Foray, 1995; Molas-Gallart, 1997; Stowsky, 2004). As James (2009) argues, the growing importance of the dual-use and the origin of technologies, along with changing national security requirements and declining European defense research budgets, have changed the dynamics of defense technological innovation, and this has opened the debate on the role of military R&D in the organization of innovation systems. Our results offer some new insights into the civilian technological role of the military industry that can spark new ideas that contribute to this debate. For example, some dual policies claim that reinforcing networks in which civilian and military firms were involved is crucial for promoting dual-use products, but what kind of network would be most efficient? Our model suggests that the military technological capability is one of the main significant factors for both the production of dual-use technologies and the *spin off/spin in* intensity, while the civilian technological capability is not relevant. This finding suggests that the key point is not just engaging defense firms in technological networks –or those with a military commercial profile– but those with greater military technological capability. By doing so, there will be more opportunities for spilling over military knowledge into civilian inventions and vice versa.

This paper is a first attempt to illuminate the role of defense firms in producing mixed patented technologies as a proxy for dual-use technological products and to study their ability to incorporate military knowledge into patented civilian inventions and vice versa. Obviously, the use of patents and patent citations has several advantages when accounting for many technological aspects of firms, as a wide range of papers has shown. However, there are down sides to this approach, and possibly, the main limitation is that the defense sector is not particularly prone to patents. We note as well that in order to carry out a quantitative analysis of the knowledge flows, we have assumed a clear line regarding the different industrial and technological areas in which defense firms develop their commercial and technological business. However, this is just an assumption. In practice, with globalization and the increase of information technologies, these boundaries are blurred. Many defense firms have become systems integrators that develop a global role and control different companies in the fields of, for example, electronics and communications. These are strong limitations, and consequently, our findings should be taken as a complement to other ways of analyzing the complexity of the relationship between the military and the civilian spheres.

## Tables

Table 1

*Averages of the Business Variables by Country (2002-2011)*

| | USA | | UK | | Trans-European | | France | |
|---|---|---|---|---|---|---|---|---|
| | Firms | Mean | Firms | Mean | Firms | Mean | Firms | Mean |
| Total sales (million US$) | 31 | 20,626.3 | 9 | 6,970.4 | 3 | 19,501.0 | 4 | 6,266.6 |
| Arms sales (million US$) | 31 | 6,295.6 | 9 | 4,207.1 | 3 | 6,191.2 | 4 | 3,419.5 |
| Profits (million US$) | 31 | 1,446.2 | 9 | 316.6 | 3 | 256.0 | 4 | 244.0 |
| Nº of employees | 31 | 63,524.5 | 9 | 29,248.7 | 3 | 44,648.3 | 4 | 22,493.7 |
| Weapon sales/sales (%) | 31 | 0.52 | 9 | 0.59 | 3 | 0.58 | 4 | 0.60 |
| | Israel | | Germany | | Italy | | Others | |
| | Firms | Mean | Firms | Mean | Firms | Mean | Firms | Mean |
| Total sales (million US$) | 3 | 1,930.0 | 5 | 13,733.6 | 6 | 4,850.7 | 10 | 11,380.0 |
| Arms sales (million US$) | 3 | 1,590.1 | 5 | 1,286.6 | 6 | 2,714.7 | 10 | 1,145.4 |
| Profits (million US$) | 3 | 71.7 | 5 | 361.7 | 6 | 88.3 | 10 | 139.4 |
| Nº of employees | 3 | 9,753.5 | 5 | 45,769.1 | 6 | 16,308.7 | 10 | 32,941.0 |
| Weapon sales/sales (%) | 3 | 0.86 | 5 | 0.40 | 6 | 0.62 | 10 | 0.47 |

Source: SIPRI and own elaboration.

Table 2

*Firms with the Highest Numbers of Total Patents (2002-2011)*

| | Nº of patents (*) | | | | Distribution (%) | | |
|---|---|---|---|---|---|---|---|
| | Total | Civilian | Military | Mixed | Civilian | Military | Mixed |
| General Electric | 18,391 | 18,108 | 4 | 5 | 98.46 | 0.02 | 0.03 |
| Honeywell International | 11,487 | 11,139 | 64 | 151 | 96.97 | 0.56 | 1.31 |
| EADS | 9,325 | 9,141 | 0 | 12 | 98.03 | 0.00 | 0.13 |
| Hewlett Packard | 9,094 | 9,024 | 0 | 0 | 99.23 | 0.00 | 0.00 |
| NEC | 8,814 | 8,727 | 24 | 26 | 99.01 | 0.27 | 0.29 |
| Mitsubishi Heavy Ind. | 5,736 | 5,700 | 0 | 8 | 99.37 | 0.00 | 0.14 |
| Mitsubishi Electric | 5,720 | 5,683 | 0 | 0 | 99.35 | 0.00 | 0.00 |
| United Technologies, UTC | 4,803 | 4,508 | 0 | 4 | 93.86 | 0.00 | 0.08 |
| Rolls Royce | 4,394 | 3,746 | 2 | 2 | 85.25 | 0.05 | 0.05 |
| Boeing | 4,304 | 4,231 | 14 | 38 | 98.30 | 0.33 | 0.88 |
| Raytheon | 3,146 | 2,461 | 283 | 157 | 78.23 | 9.00 | 4.99 |
| Harris | 2,370 | 2,265 | 0 | 2 | 95.57 | 0.00 | 0.08 |
| CEA | 1,951 | 1,943 | 0 | 0 | 99.59 | 0.00 | 0.00 |
| Northrop Grumman | 1,463 | 1,404 | 9 | 19 | 95.97 | 0.62 | 1.30 |
| MTU Aero Engines | 1,448 | 1,443 | 0 | 1 | 99.65 | 0.00 | 0.07 |
| Top 15 (*) | 92,446 | 89,523 | 400 | 425 | 96.84 | 0.43 | 0.46 |
| Others | 13,735 | 10,033 | 2,026 | 718 | 73.05 | 14.75 | 5.23 |
| Total | 106,181 | 99,556 | 2,426 | 1,143 | 93.76 | 2.28 | 1.08 |

Source: PATSTAT and own elaboration.
(*) The difference between the total number of patents and the number of civilian, military and mixed patents corresponds to the patents that could not be classified due to lack of information about the IPC codes in the database.

Table 3

*Firms with the Highest Number of Mixed Patents (2002-2011)*

| | Nº of patents (*) | | | | Distribution (%) | | |
|---|---|---|---|---|---|---|---|
| | Total | Civilian | Military | Mixed | Civilian | Military | Mixed |
| Rheinmetall | 1,120 | 227 | 702 | 158 | 20.27 | 62.68 | 14.11 |
| Raytheon | 3,146 | 2,461 | 283 | 157 | 78.23 | 9.00 | 4.99 |
| Honeywell International | 11,487 | 11,139 | 64 | 151 | 96.97 | 0.56 | 1.31 |
| Diehl | 654 | 342 | 185 | 81 | 52.29 | 28.29 | 12.39 |
| Krauss-Maffei Wegmann | 321 | 62 | 192 | 66 | 19.31 | 59.81 | 20.56 |
| MBDA (BAE Systems, EADS; Finmecannica) | 315 | 148 | 68 | 63 | 46.98 | 21.59 | 20.00 |
| Nexter | 426 | 112 | 245 | 58 | 26.29 | 57.51 | 13.62 |
| Saab | 741 | 515 | 156 | 47 | 69.50 | 21.05 | 6.34 |
| Boeing | 4,304 | 4,231 | 14 | 38 | 98.30 | 0.33 | 0.88 |
| Textron | 929 | 880 | 8 | 37 | 94.73 | 0.86 | 3.98 |
| BAE Systems | 1,379 | 913 | 57 | 36 | 66.21 | 4.13 | 2.61 |
| BAE Systems Inc. (BAE Systems, UK) | 416 | 339 | 32 | 32 | 81.49 | 7.69 | 7.69 |
| NEC | 8,814 | 8,727 | 24 | 26 | 99.01 | 0.27 | 0.29 |
| Lockheed Martin | 1,046 | 973 | 35 | 22 | 93.02 | 3.35 | 2.10 |
| QinetiQ | 1,321 | 1,121 | 34 | 21 | 84.86 | 2.57 | 1.59 |
| Top 15 | 36,419 | 32,190 | 2,099 | 993 | 88.39 | 5.76 | 2.73 |
| Others | 69,762 | 67,366 | 327 | 150 | 96.57 | 0.47 | 0.22 |
| Total | 106,181 | 99,556 | 2,426 | 1,143 | 93.76 | 2.28 | 1.08 |

Source: Own elaboration and PATSTAT.
(*) The difference between the total number of patents and the number of civilian, military and mixed patents corresponds to the patents that could not be classified due to lack of information about the IPC codes in the database.

Table 4

*Descriptive Statistics (*)*

| | | | | |
|---|---|---|---|---|
| Nº of mixed patents | 16.0986 | 34.3433 | 0 | 158.0000 |
| Nº of military citations in civilian patents | 10.3944 | 32.4757 | 0 | 218.0000 |
| Nº of civilian citations in military patents | 5.2817 | 15.8486 | 0 | 88.0000 |
| Civilian technological capability | 0.4093 | 1.1920 | 0 | 9.3638 |
| Military technological capability | 0.0203 | 0.0573 | 0 | 0.3191 |
| Size (log of the nº of employees) | 9.7768 | 1.3698 | 7.1011 | 12.6910 |
| Location (US=1) | 0.4366 | 0.4995 | 0 | 1 |
| Military commercial profile | 0.5325 | 0.2777 | 0.0202 | 1 |

(*) Nº of obs: 71.

Table 5

*Correlations*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Nº of mixed patents | 1 | | | | | | | |
| 2 | Nº of military citations in civil pat | 0.5629 | 1 | | | | | | |
| 3 | Nº of civilian citations in milit pat | 0.8602 | 0.5958 | 1 | | | | | |
| 4 | Civilian technological capability | 0.2227 | 0.0341 | 0.1535 | 1 | | | | |
| 5 | Military technological capability | 0.5855 | 0.1266 | 0.3871 | 0.4195 | 1 | | | |
| 6 | Size (log of the nº of employees) | 0.1762 | 0.2484 | 0.0975 | -0.1799 | -0.2236 | 1 | | |
| 7 | Location (US=1) | 0.0329 | 0.2253 | 0.1396 | -0.1481 | -0.2721 | 0.2219 | 1 | |
| 8 | Military commercial profile | 0.0827 | 0.1354 | 0.1222 | 0.3359 | 0.164 | -0.5149 | -0.0744 | 1 |

Table 6

*Effects of Firm's Technological Capability on Mixed Patent Production*

| | Poisson model | Negative Binomial |
|---|---|---|
| | Coefficient (Std. error) | Coefficient (Std. error) |
| Civilian technological capability | 0.058 | 0.400 |
| | (0.079) | (0.399) |
| Military technological capability | 12.088*** | 19.063*** |
| | (1.130) | (4.647) |
| Size (log of the nº of employees) | 0.639*** | 0.809*** |
| | (0.134) | (0.171) |
| Military commercial profile | 1.679 | 1.625* |
| | (1.147) | (0.876) |
| Location (US=1) | 0.647 | 0.738* |
| | (0.420) | (0.414) |
| _cons | -5.592*** | -7.857*** |
| | (1.701) | (1.942) |
| /lnalpha | | 0.799*** |
| | | (0.211) |
| alpha | | 2.224 |
| LR test of alpha=0 | | 1.118.529*** |
| Log-Likelihood | -756.80 | -197.54 |
| chi2 | 153.840*** | 38.908*** |
| Mean VIF (1) | 1.34 | 1.34 |
| Number of observations | 71 | 71 |
| Adjusted R2 | 0.513 | 0.090 |
| Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. (1) Values between 1.12 and 1.5. | | |

Table 7

*Knowledge Inflow into Technologies Produced by Top Defense Firms (2002-2011)*

| Company | Number of Citations | | | | | Distribution of citations (total *firm$_i$*=100) | | |
|---|---|---|---|---|---|---|---|---|
| | Total | Cit/pat | Civ. | Mil. | Mix. | Civ. | Mil. | Mix. |
| Honeywell International | 45,318 | 3.95 | 44,251 | 170 | 543 | 97.65 | 0.38 | 1.20 |
| General Electric | 44,450 | 2.42 | 44,004 | 5 | 25 | 99.00 | 0.01 | 0.06 |
| Hewlett Packard | 26,156 | 2.88 | 25,929 | 3 | 6 | 99.13 | 0.01 | 0.02 |
| Boeing | 21,024 | 4.88 | 20,640 | 52 | 120 | 98.17 | 0.25 | 0.57 |
| United Technologies, UTC | 14,860 | 3.09 | 14,709 | 8 | 49 | 98.98 | 0.05 | 0.33 |
| NEC | 11,227 | 1.27 | 11,085 | 24 | 6 | 98.74 | 0.21 | 0.05 |
| Raytheon | 9,729 | 3.09 | 7,477 | 1,609 | 484 | 76.85 | 16.54 | 4.97 |
| Harris | 8,300 | 3.50 | 8,160 | 1 | 6 | 98.31 | 0.01 | 0.07 |
| Pratt & Whitney (UTC) | 6,879 | 8.01 | 6,831 | 2 | 7 | 99.30 | 0.03 | 0.10 |
| EADS | 6,556 | 0.70 | 6,431 | 11 | 17 | 98.09 | 0.17 | 0.26 |
| Rolls Royce | 5,677 | 1.29 | 5,616 | 5 | 7 | 98.93 | 0.09 | 0.12 |
| Lockheed Martin | 4,658 | 4.45 | 4,400 | 117 | 96 | 94.46 | 2.51 | 2.06 |
| Mitsubishi Electric | 4,572 | 0.80 | 4,501 | 0 | 2 | 98.45 | 0.00 | 0.04 |
| Mitsubishi Heavy Industries | 4,417 | 0.77 | 4,361 | 2 | 3 | 98.73 | 0.05 | 0.07 |
| Northrop Grumman | 4,024 | 2.75 | 3,923 | 9 | 39 | 97.49 | 0.22 | 0.97 |
| Top 15 | 217,847 | 2.40 | 212,318 | 2,018 | 1,410 | 97.46 | 0.93 | 0.65 |
| Others | 23,724 | 1.56 | 20,243 | 2,375 | 835 | 85.33 | 10.01 | 3.52 |
| Total | 241,571 | 2.28 | 232,561 | 4,393 | 2,245 | 96.27 | 1.82 | 0.93 |

This table lists the top 15 defense companies with the highest number of citations.
Source: Own elaboration and PATSTAT.

Table 8

*Knowledge Inflow by Top Defense Firms (2002-2011)*

| Company | *Spin off* | | | *Spin in* | | |
|---|---|---|---|---|---|---|
| | Military and mixed pat citations in civ. Pat (1) | Total military and mixed citations (2) | % Average *spin off* (1)/(2) | Civilian pat citations in military pat (3) | Total civilian citations (4) | % Average *spin in* (3)/(4) |
| Raytheon | 218 | 2,093 | 10.42 | 88 | 7,416 | 1.19 |
| Boeing | 128 | 172 | 74.42 | 14 | 20,922 | 0.07 |
| Alliant Techsystems | 88 | 263 | 33.46 | 1 | 983 | 0.10 |
| Lockheed Martin | 65 | 213 | 30.52 | 6 | 4,401 | 0.14 |
| Rheinmetall | 45 | 991 | 4.54 | 69 | 394 | 17.51 |
| Diehl | 31 | 225 | 13.78 | 5 | 367 | 1.36 |
| General Electric | 30 | 30 | 100.00 | 0 | 44,446 | 0.00 |
| L-3 Communications | 25 | 25 | 100.00 | 0 | 1,342 | 0.00 |
| Saab | 20 | 268 | 7.46 | 6 | 537 | 1.12 |
| Nexter | 11 | 371 | 2.96 | 18 | 90 | 20.00 |
| Israel Aerospace Industries | 11 | 22 | 50.00 | 0 | 158 | 0.00 |
| Krauss-Maffei Wegmann | 10 | 192 | 5.21 | 5 | 48 | 10.42 |
| QinetiQ | 10 | 72 | 13.89 | 17 | 1,856 | 0.92 |
| Textron | 10 | 77 | 12.99 | 0 | 1,860 | 0.00 |
| Elbit Systems | 8 | 20 | 40.00 | 0 | 165 | 0.00 |
| Top 15 | 710 | 5,034 | 14.10 | 229 | 84,985 | 0.27 |
| Others | 28 | 1,604 | 1.75 | 146 | 147,576 | 0.10 |
| Total | 738 | 6,638 | 11.12 | 375 | 232,561 | 0.16 |

(1) Total number of military and mixed patents cited by the firm in its civilian patents.
(2) Total number of military and mixed patents cited by the firm in all its patents.
(3) Total number of civilian patents cited by the firm in its military patents.
(4) Total number of civilian patents cited by the firm in all its patents.

Table 9

*Factors Affecting the* "Spin off" *and the* "Spin-in" *Processes*

| | Spin-off (military or mixed patent citations in civilian patents) | | Spin-in (civilian patent citations in military patents) | |
|---|---|---|---|---|
| | Poisson model | Negative Binomial | Poisson model | Negative Binomial |
| | coef/se | coef/se | coef/se | coef/se |
| Civilian technological capability | -0.077 | 0.395 | 0.003 | 0.984 |
| | (0.113) | (0.604) | (0.143) | (0.635) |
| Military technological capability | 13.552*** | 17.766*** | 17.269*** | 19.103*** |
| | (2.124) | (6.553) | (3.555) | (7.213) |
| Size (log of the nº of employees) | 0.751*** | 0.949*** | 0.377 | 0.272 |
| | (0.237) | (0.334) | (0.347) | (0.267) |
| Military commercial profile | 3.020*** | 2.893* | 2.391 | 2.026 |
| | (1.000) | (1.501) | (1.921) | (1.668) |
| Location (US=1) | 1.985*** | 1.802** | 2.771** | 2.953*** |
| | (0.663) | (0.735) | (1.248) | (0.759) |
| _cons | -8.833*** | -11.043*** | -6.061* | -5.505* |
| | (2.753) | (3.544) | (3.357) | (3.203) |
| /lnalpha | | 1.745*** | | 1.898*** |
| | | (0.259) | | (0.286) |
| alpha | | 5.727 | | 6.674 |
| LR test of alpha=0 | | 1.205.351*** | | 646.777*** |
| Log-Likelihood | -740.87 | -138.19 | -427.68 | -104.29 |
| chi2 | 45.410*** | 21.333*** | 61.597 | 18.431 |
| Mean VIF (1) | 1.34 | 1.34 | 1.34 | 1.34 |
| Number of observations | 71 | 71 | 71 | 71 |
| Adjusted R2 | 0.495 | 0.072 | 0.449 | 0.081 |

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.
(1) Values between 1.12 and 1.5.

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## Notes

[1]Some authors use the term "*spin in*" for this process (Garcia-Alonso & Smith, 2017; James, 2006; Kirchberger & Pohl, 2016; Molas-Gallart, 2002), while others call it "*spin on*" (e.g. Alic et al., 1992; Anteroinen, 2010; Stowsky, 2004; Willett, 1994).

[2]SIPRI Arms Industry Database (https://www.sipri.org/databases/armsindustry). This database contains information about the world's top 100 defense companies.

[3]The K.U.Leuven/EUROSTAT method for harmonized patent applicants' names is a comprehensive procedure to achieve patentee names in an automated way.