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# Dual-Use Technology and Defence–Civilian Spillovers: Evidence from the Norwegian Defence Industry

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# Abstract

Spillovers from defence-industrial developments have strongly influenced civilian technologies. Despite the international academic and political interest in defence–civilian spillovers, little is known as to whether the Norwegian defence industry affect civilian innovation. This thesis investigates the extent of defence–civilian spillovers of dual-use technologies from the Norwegian defence industry, and factors facilitating this.

The thesis builds on a mixed-methods application of quantitative and qualitative approaches. From an extensive collection of Norwegian defence patents and subsequent international citations, from 1970 until 2012, the study provides a new empirical dataset with quantitative evidence of defence–civilian spillovers. Through a combination of patent data and detailed firm-level data, statistical analyses test the relevance of several hypothesised explanatory factors for spillover. The study further provides qualitative evidence from interviews of company representatives on dual-use technology and the factors affecting spillover.

The main findings show that the military developments of the Norwegian defence industry have in the last decades generated substantial spillovers in the form of dual-use technology to civilian industries. This has increased in the latest decade, contrary to what other scholars have claimed. The international component is substantial compared to domestic spillovers, indicating that most Norwegian dual-use technologies are utilised abroad. Several factors affect this diffusion of technology. Company investments in R&D, collaboration with research institutes, and the facilitation of broad technological knowledge bases affect civilian usage of military technologies. Moreover, a heightened focus on civilian production increases the potential for spillovers, just as a greater defence focus acts to decrease inter-sectoral spillovers. The main findings support international studies of dual-use technology by broadening the explanatory factors and expanding on how empirical data can be collected.

A general implication of these findings is that policies implemented for supporting military development in the Norwegian defence industry have had indirect civilian benefits. Nonetheless, these policies should be strengthened to encourage civilian Norwegian firms to take greater advantage of military developments – an area in which civilian firms in other countries have been far more active.

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# 1. Introduction

For centuries, military establishments have exerted influence, providing national security as well as domestic industrial growth in many nations (Mowery, 2010). With heightened political tensions during the second half of the twentieth century, the channels through which military activity influenced innovation changed significantly (Mowery, 2010). With increased expenditures on research and development (R&D) and procurements in peacetime as well as in wartime, investments in military technology found new and broader areas of application.

Military developments have resulted in a vast range of technological innovations. Some of these technologies have later spilled over to civilian applications and uses (Mowery, 2012). Examples of defence–civilian spillovers can be found in many spheres of everyday life. For instance the Internet, where the US Department of Defense played a critical role in funding R&D of its earliest forerunner, ARPANET (Mowery, 2010, p. 1250). The Global Positioning System now found in your sports watch was originally intended for calculating the launch-point trajectories of ballistic missiles, and you might still have been flying on a propeller aircraft if it had not been for the heavy defence research in jet-speed technology (Mowery, 2010, p. 1237).

It is still debated how and why military innovation could affect the broader economy through spillovers of technological innovations (Mowery, 2010, p. 1234). Moreover, the secrecy of the defence industry makes it difficult to trace the innovations that might spill over to commercial industries. Nevertheless, some scholars (e.g. Alic, Branscomb, Brooks, Carter & Epstein, 1992) have studied the technological innovations that have done so, and have developed the concept of a specific type of spillover, termed 'dual-use' technology, to capture the characteristics of technologies developed by defence industries and later used by civilian sectors.

The relatively few studies on this topic have shown that defence industries have played a substantial role in the development of new technologies that have resulted in benefits to society as a whole (Mowery, 2012). However, these studies have focused mainly on the large defence industries in the US, France and the United Kingdom. Additionally, academic interest was at its peak in the late stages of the Cold War era, due to the large defence budgets and costly procurements. With the end of the Cold War, policymakers wanted to know whether continued support of defence developments could be justified, so that these would in addition to supporting domestic defence industries, also yield defence–civilian spillovers.

This has also been an aim of policy in Norway (Norwegian Ministry of Defence [MoD], 2006). However, to my knowledge, no one has examined whether the Norwegian Defence industry with its technological developments has contributed to defence–civilian spillovers of dual-use technology. By studying the Norwegian defence industrial base I intend to investigate whether an industry with military capabilities benefits civilian technological developments, and if international empirical evidence and theory-based knowledge can explain such spillovers in a Norwegian context.

## 1.1 Background and Objectives

A technology that is invented in the defence industry or in a civilian industry, and is used in the other, is known as a dual-use technology (Stowsky, 2004). The concept of dual-use technology as a type of spillover of technology is complex and has been studied in various forms, using multiple methodological approaches. Since its conception the concept has been related to defence-industry developments as an indirect result of military innovations, particularly throughout the Cold War era. During this period several technologies originally developed for military purposes subsequently spilled over to civilian technologies. Examples are numerous, ranging from product technologies to process technologies (Mowery, 2010).

While there have been a considerable number of studies investigating the massive expenditures on military procurement during the second half of the twentieth century, few have focused explicitly on the defence–civilian spillovers of dual-use technologies (Mowery, 2010). The studies that have done so have concentrated mainly on case studies within the geographical frame of the US defence industry (e.g. Alic et al., 1992; Reppy, 1999; Kelley & Watkins, 1995), as well a few European countries (see e.g. Molas-Gallart & Sinclair, 1999; James, 2000; Buesa, 2001). These studies show that there are clear indications of a flow of dual-use technologies from national defence industries to civilian industries.

Although military technologies have diffused into well-known applications in everyday life, civilian innovations have also found applications in defence technologies. There are examples showing that information and communication technologies (ICT) and the continuous civilian demand for better products at lower costs have led the military industry to adopt far more advanced civilian applications to their own use. The changes in market dynamics seem also to have redirected the perspectives of researchers, to focus on civilian innovative capacity and how this affects military innovations (Stowsky, 2004).

In fact, these changes have contributed in some cases to a virtuous cycle of technological flow, significant for the development of both defence and civilian dual-use technologies (Amorelli, 1996).

The Norwegian defence industry is considered as a sector that invests large amounts in R&D, and is more innovative than other domestic industries (Fevolden, Andås & Christiansen, 2009). Oddly enough, even though civilian innovations have surpassed military developments in some areas, the Norwegian defence industry has received limited academic attention. The industry produces a wide range of products and process technologies, which are highly demanded both abroad and within Norway (Castellacci & Fevolden, 2012). The industry is also well known as one of the more innovative sectors in Norway, where even the smallest firms report substantial innovative activities (Fevolden et al., 2009, pp. 14–15).

The influential character of military technologies and applications is often discussed in ethical discourses, and the defence industry is occasionally regarded as unethical, as it deals in products and processes that are used for the purpose of warfare. Such discussions are important, hence also legitimising the need for further study of the industry, and whether its military developments could generate indirect civilian benefits.

In order to study the Norwegian defence industry and the degree of defence–civilian spillovers of dual-use technology to civilian industries, I have formulated the following research questions for this thesis:

**(i) What is the extent of defence–civilian spillovers from the Norwegian defence industry to civilian sectors?**

**(ii) What factors explain this pattern of defence–civilian spillover?**

Earlier works on defence–civilian spillovers have applied many different methodology approaches to the study of dual-use technologies. In this thesis I have chosen to approach the research questions through the use of both quantitative and qualitative methods: a mixed-methods approach. This enables both an extensive and in-depth mapping of defence–civilian spillovers, as well as a thorough analysis of various possible explanatory factors.

The first research question is answered on the basis of an extensive collection of Norwegian military patents and subsequent civilian citing patents across the world. In addition, interviews of key personnel of five defence firms chosen as the most dual-use-producing defence firms in the industry provide insights and further in-depth knowledge.

The main findings from the statistical analysis show that defence–civilian spillovers of dual-use technologies can be observed, and have actually increased in the past decade. The international distribution of spillovers is substantial when compared to domestic use of defence technologies. Moreover, the qualitative approach shows several examples of dual-use technologies where some are found among the patents. The number and complexity of these examples seem to vary between the large and small- and medium sized defence firms.

The second research question is answered through analysis of four factors assumed to affect defence–civilian spillovers. It is hypothesised that collaborating with external firms, enabling broad technological competencies, orientation towards civilian productions, and increased innovative capabilities will affect spillovers positively. The statistical analysis tests this through several logistic regressions employing both patent data and detailed firm-level data. The qualitative approach with semi-structured interviews goes deeper into these explanatory factors, seeking to uncover more complex explanations of such diffusion.

The main findings show that technological breadth, civilian orientation, innovative capabilities and external cooperation do affect defence–civilian spillovers of dual-use technology. This is supported by the interviews, which indicate that external collaboration with research institutes in product development has been shown to affect spillovers.

## 1.2 Overview of Thesis

Chapter two gives an overview of the Norwegian defence industry. Presenting the structural layout, innovative capabilities, and the governmental policy framework that has moulded the industry. This functions as an essential contextual background for the study.

Chapter three provides the foundation of the theoretical framework in the thesis and presents the concept of dual-use technology and four hypothesised explanatory factors for defence–civilian spillover. These four explanatory factors constitutes the base for the second research question, which will in addition to the first research question, be empirically reviewed in chapter five and six.

Chapter four describes the methodology and the data. It discusses the mixed methods research design, and how both the quantitative and qualitative data have been collected and analysed to answer the research questions.

Chapter five presents the empirical results from the quantitative approach. The first part presents descriptive statistics of the empirical collection, answering the first research question. The following sections show the results of the statistical analysis of the four hypothesised factors for spillover, answering the second research question.

Chapter six presents findings from interviews of the five most dual-use producing defence firms of the industry. The first sections briefly describe each defence firm and continue by discussing examples of spillovers to answer the first research question. In the final sections before summarising the results, several sections provide a qualitative discussion of the explanatory factors.

Finally, chapter seven answers the research questions, and concludes the combined quantitative and qualitative main findings, before policy implications and suggestions for further research is offered.

# 2. Context

## 2.1 The Norwegian Defence Industrial Base

The Norwegian defence industry consists of many heterogeneous firms delivering multiple product and process technologies to both military and civilian customers (Tvetbråten, 2011). As with other nations defence industries, the Norwegian defence industry is defined on the basis of several aspects. To fully comprehend the defence industry, we must see it in relation to the composition of firms, to other nations defence industries, the innovative capabilities, but also the policies that have shaped and continue to shape the industry.

Defence industries in general are sometimes characterised as an unethical industry, exporting military goods to despots and fuelling armed conflicts. However, what is often neglected in the public debates on the industry is the magnitude of its importance to security, innovation and national economies (Mowery, 2010). The Norwegian defence industrial base is considered no different. Traditionally, the industry is believed to follow with two important types of policies. Foremost, it is believed that defence companies could contribute to domestic economic growth and international significance by introducing advanced innovations as well as providing positive spillover effects to surrounding civilian industries (Blom, Castellacci & Fevolden, 2012; Wicken, 1990). Second, the industry is considered important by that it provides the Norwegian armed forces with access to high-end technologies and by ensuring a secure flow of components, munitions and expertise in times of crisis (Blom et al., 2012; MoD, 2006).

The Norwegian defence industry is defined as the constellation of firms engaged in the market of defence and security solutions that contribute to national creation of value over time and that are localised in Norway, independent of ownership (Tvetbråten, 2011; Fevolden et al., 2009). Within the Norwegian context, companies are identified through their membership in the Norwegian Defence and Security Industries Association (FSi[1]). These are companies with approved export licences or that have track records of large deliveries to Norwegian armed forces (Tvetbråten, 2011). The Norwegian defence industry consists of a population of 100 heterogeneous companies, with both large firms and small or medium-sized (SME) enterprises (Blom et al., 2012; Tvetbråten, 2011). The heterogeneity of these firms are so prevalent that the enterprises often have nothing more in common than that they deliver products or services of military art to their own nation or other nation's armed forces

[1] The Norwegian Defence and Security Industries Association, FSi. http://www.fsi.no/fsi_english/home/

(Fevolden et al., 2009). The most influential actors of the industry are a limited number of large multi-product and multi-competence companies characterised as 'system integrators'. These companies deliver complete weapon systems or platforms based on integration of a broad group of technologies (Blom et al., 2012, pp. 5–9). These are well known companies such as Kongsberg Defence and Aerospace and Nammo. The rest, and the large part of the industry consist of companies that are of micro, small or medium-sized described as 'specialised suppliers', in that they produce specialised components or stand-alone military equipment based on high-end technological expertise (e.g. Nera, Nacre and Simrad Optronics). The former categorisation of defence firms as specialised suppliers and system integrators is a distinction set by Castellacci and Fevolden (2012) and Blom et al. (2012), on the basis of Keith Pavitt's (1984) taxonomy. In addition to the mentioned firms in the industry, there are also larger civilian companies with a small military business on the side (e.g. Deloitte and IBM).

The composition of defence firms' sizes in the industry is presented in figure 2.1 below, from Fevolden, Karlsen and Ringdal (2008, p. 11). The firms were selected through their membership in the Norwegian defence and security association, and distributed along firm size categories. The figure shows that there are some large firms (11%) and a greater number of micro-, small- and medium-sized companies (89%), which is in accordance with Blom et al. (2012). What is important to consider in this figure, is that the companies have been distributed by how many employees they have working on defence. Thus, a large company with several thousand employees may have only 30 people engaged in defence, which classifies the firm as a small-sized defence firm (Fevolden et al., 2008).

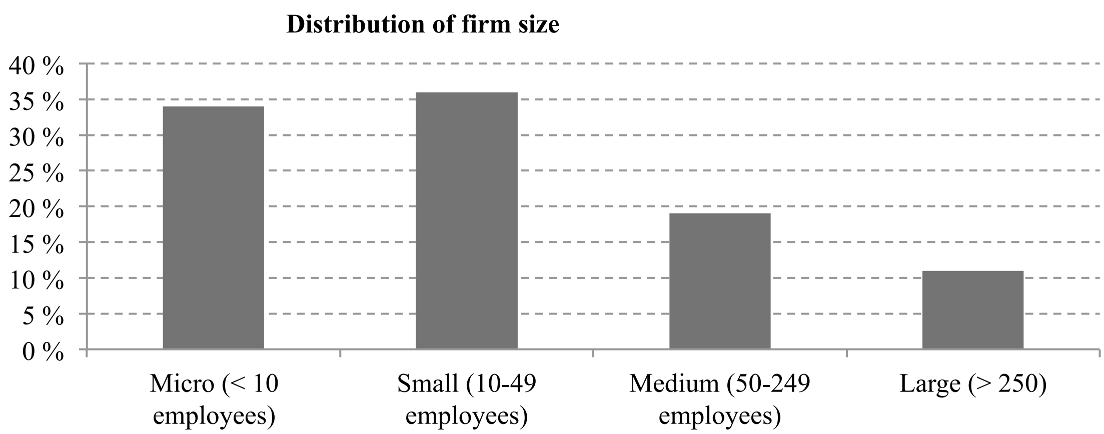


**Figure 2.1** Distribution of firm size. Source: Fevolden et al. (2008, p. 11).

At the industrial level, the Norwegian defence industry stands out from other domestic industries (Fevolden et al., 2009). In an international perspective, however, the Norwegian defence industry is not reckoned among the major industries. Bitzinger (2003, p. 6) notes that the global arms industry could be divided into three types of arms producers: first-tier, second-tier, and third-tier industries. The leading and most influential industries, such as those of the UK, France, Germany and the US, are termed as first-tier arms producers. These industries deliver complete products and are the most technologically advanced defence producers, aiming at sustaining autarky. The second-tier group consists of various countries with small but quite sophisticated defence industries (e.g. Norway, Sweden, Canada). Some of these are specialised in niche production, where some stand out when compared to one another. In particular, Sweden is considered as one of the most successful (Bitzinger, 2003, p. 64). However, even if the defence industries of Sweden and Norway are considered as second-tier industries, they do differentiate. When comparing Norway's industry with the Nordic defence industries, Norway takes a middle position (Fevolden & Tvetbråten, 2013). The Norwegian defence industry is larger and more sophisticated than the Danish industry, but much smaller and less diversified than the Swedish industry (Fevolden & Tvetbråten, 2013). At the lower level of the hierarchy are the third-tier industries. Industries in countries like Egypt and Nigeria are characterised as possessing only basic arms producing capabilities (Bitzinger, 2003, p. 6).

## 2.2 Innovation and R&D

The Norwegian defence industry is small compared to other nations defence industries (Bitzinger, 2003). However, the industry has a wide span of technological competencies, and produces everything from tactical communications and crypto solutions to multi-purpose ammunition and field rations (Blom et al., 2012). Although the companies could be considered fairly heterogeneous, some key areas of competence stand out in the industrial context. The industry's areas of competence evolve around a knowledge and technological domain where Norwegian firms seemingly have a comparative advantage (Fevolden et al., 2009, p. 48). Table 2.1 illustrates the distribution of where the companies themselves allocate their competence within pre-defined technological areas, designed by the Ministry of Defence

(MoD, 2006, p. 12). The distribution is the result of a survey[2] conducted in 2008 by the Norwegian Defence Research Establishment (FFI), and presented and discussed in Fevolden, Christiansen & Karlsen (2011).

**Areas of competence**

| **Technological areas of competence** | **Total** |
|---|---|
| Information and communication technology | 23 |
| System integration | 20 |
| Missile technology and autonomous weapons and sensor systems | 9 |
| Sub-sea technologies | 6 |
| Simulation technologies | 8 |
| Weapons and rocket technology, ammunition and military grade explosives | 4 |
| Material technology | 10 |
| Marine technology | 10 |
| No suitable classification | 12 |
| Total | 102 |

**Table 2.1** Distribution of defence firms after the Ministry of Defence's technological areas of competences. The firms have on average selected two areas of competence each. Source: Fevolden et al. (2011, p. 22).

The industry report to have most competencies within: information and communication technologies, and system integration. Contrary to a common assumption of defence industries, only a small share of the companies report competencies in the production of weapons and ammunition (Fevolden et al., 2011, p. 21). Table 2.1 shows the areas where the different firms themselves report of having competencies.

In another report, Fevolden et al. (2009) used two other indicators: export data and the European Defence Agency's technology taxonomy[3] to measure in which technological areas the defence industry are competent in. The results of this analysis indicate that the industry

[2] The VIFIN-survey, 'Verdiskapning i forsvarsindustrien'. The questions and the related indicators in the survey refer to the year of 2006 (Castellacci & Fevolden, 2012, p. 16).

[3] The EDA taxonomy of technologies contains about 200 defence-related technologies that are assigned to 32 areas. The taxonomy does not consider civilian technological areas even if these are important areas to many defence enterprises.

stands out in: information and communication technologies; material and mechanical technologies; and systems integration of electronic, mechanical and CCI (command, control and information) technologies (Fevolden et al., 2009, p. 56).

In terms of innovativeness and expenditure on R&D the industry stands out compared to other domestic industries (Fevolden et al., 2009). In general, Mowery (2010) notes that defence industries is on average characterised by very high levels of technological opportunities and a strong degree of company level innovativeness. Kari Tvetbråten (2011, p. 15–16) collected and analysed data on the characteristics of the defence industry. She found that the industry invested in 2010 1 billion NOK on R&D, an expenditure that makes out 7% of the total revenue of 14.2 billion NOK in the defence market[4]. Here the results also indicate that the SMEs are those investing the most. It is prominent that the high demands of durability and precision technologies that are not immediately 'off the shelf' require large investments in R&D. Therefore the industry is characterised as highly knowledge-intensive (Fevolden et al., 2009). Results from Statistics Norway's R&D and innovation survey presented in Fevolden et al. (2009) shows that the industry is more innovative on average than other domestic industries. The results put forth show that 58% of the companies in the industry report that they have conducted product and/or process innovations, other industries report in total only 21%. Even the smallest firms report continuous process and product development. When compared to differences of R&D activities the dissimilarities are even greater, with 53% in the defence industry versus 12% in civilian industries (Fevolden et al., 2009).

The heavy investments in R&D, the high innovation intensity, and the industries areas of competence have resulted in several products with both national and international success. Despite the size of the industry, it is considered as highly export intensive when compared to other European defence firms (Castellacci & Fevolden, 2012). One of the technologies with great export success is Kongsberg Defence and Aerospace's 'Protector', a multi-role weapon station that has seen deployment in newer armed conflicts by several nations (Castellacci & Fevolden, 2012). Success has not only been seen in areas of weapons and ammunition, but as well as in electronics. This segment is where Norwegian defence companies produce the most varied set of technologies, spanning from a wide range of encryption systems, communication equipment to lasers and sonars (Castellacci & Fevolden, 2012, p. 33). Some of the technologies have not only been highly requested by the military, but also experienced considerable civilian demand (Castellacci & Fevolden, 2012, p. 35).

[4] Tvetbråten (2011, p. 10) comments explicitly that this revenue represents sales of products that could have both military and civilian applications.

## 2.3 Industrial Policies

The industrial policies that have been tasked to promote a viable defence industry, supporting the armed forces and promoting export and domestic industrial development, has remained the main defence industrial policies since the early post World War II years (Blom et al., 2012; Fevolden & Tvetbråten, 2013; Fevolden et al., 2011). The development of the Norwegian defence industry has been greatly influenced by these policies after the Second World War, but also from Norway's NATO membership. Unlike Sweden, which has remained neutral and needed to be self-sufficient, Norway has by its membership been able to rely on NATO members for other types of defence material (Fevolden & Tvetbråten, 2013). Policy makers have never wished to seek a fully self-sufficient industry, but an industry that could provide armed forces with military components and maintenance capacities (Fevolden & Tvetbråten, 2013).

The two main institutions in the policy landscape today are Innovation Norway and the Norwegian Ministry of Defence. However, they support the industry through different means. Innovation Norway supports the industry through a variety of measures that aim at supporting innovation and internationalisation of primarily small and medium-sized firms (Blom et al., 2012). The Ministry of Defence on the other hand attempt to support firms that contribute to the secure provision of services and products to the armed forces. Focusing their measures on R&D programmes and stimulating offset agreements (Blom et al., 2012).

Fevolden and colleagues (2008) discuss these policies in addition to several others. They report that there are numerous policies directed towards the industry. Furthermore, they point out that a coordination of the policy instruments would prove advantageous. However, whether the policy goals are compatible or if the policies support one another is an open question (Blom et al., 2012, p. 10). Fevolden et al. (2008) and Fevolden and Tvetbråten (2013) note that one of the most important policy instruments that the Norwegian Government has used to stimulate the defence industry is the offset agreement. This has played a significant role in encouraging exports with a limited domestic market (Fevolden & Tvetbråten, 2013).

The defence industry has evolved into what it is today due to governmental support. The industry's competencies have developed from the many demands by the armed forces, which have procured technologies to their specific use. Therefore, the industry does not produce airplanes, vehicles or large marine vessels, but highly advanced systems that can be integrated in various applications. According to Torbjørn Svensgård, President of FSi, (lecture held at Oslo Military Society, 26 March 2012) this has led the industry to become a significant international supplier of subsystems worldwide. In addition, the industry has been successful in applying these technologies for civilian purposes. ‘Thus, “dual use” is another shared quality by the industry’ (Svensgård, 2008, p. 4).

## 2.4 Concluding Remarks

The Norwegian defence industrial base is a heterogeneous industry comprising of firms of various sizes and competencies. The composition and capabilities of this industry has been moulded by governmental policies especially after WWII. These policies have contributed to define what the industry is today. Both in comparison to other nations defence industries, but also which type of capabilities the industry is sought to possess. Nonetheless, the discussions of the constructs of this industry are important by that it is the basis for the empirical data collection and analyses. Even though the industry is considered no major defence industry in global comparisons – It still holds capabilities that could be of importance by generating defence–civilian spillovers. Hence, the industry is highly innovative and spends significant amounts on R&D compared to domestic industries (Fevolden et al., 2009). This has resulted in several successful products and process innovations that experiences international demand, both from military and civilian sectors.

# 3. Theory and Hypotheses

Several articles have discussed defence–civilian spillovers of dual-use technologies. Even if the concept of this spillover might pertain as a fairly straightforward concept, the literature suggests otherwise. The concept is and has been strongly influenced by governmental policies, but also by varying interpretations on how it should be defined. Nonetheless, some consistency can be detected, and functions as to define the concept, as well as to divide the academic discussions into four explanatory factors for this spillover.

The diffusion of defence industrial innovations, and how this compares with the diffusion of civilian-sector innovations has long been the object of debate in the literature. According to Cowan and Foray (1995, p. 851), there is now a sizable literature concerned with the relationship between military and civilian technologies. In particular a discourse has evolved around the fear of proliferation of weapon-graded technology, as well as an adjunct to achieve industrial conversion during times of decreasing budgets and defence procurements (Avadikyan, Cohendet & Dupouët, 2005). Moreover, there are two sides to this story. Since the 1980s, some authors have especially studied the use of military innovations for civilian purposes, and termed such technology usage as 'dual-use' (Acosta, Coronado & Marín, 2011). Moreover, researches have also studied the tendency of military usage of civilian technology, such as the adoption of several ICT services for military applications (Avadikyan et al., 2005; Cowan & Foray, 1995; Mowery, 2010; Reppy, 1999), which could also be perceived as 'dual-use'. Nonetheless, the main body of literature seem to emphasise that the point of interest is in how defence industrial innovations spill over towards civilian sectors, in which there are numerous examples of (e.g. Global Positioning System, radar, and semiconductors).

The spillover direction from defence to civilian of dual-use technologies is the direction of focus in this thesis. The concept of dual-use technologies is therefore defined out from this perspective. Moreover, the section on the definition does show that there are multiple interpretations of defence–civilian spillovers. This aspect is further emphasised in a discussion of governmental policies. The final sections attempts at collectively present and discuss earlier studies of dual-use technology to show evidence of defence–civilian spillovers from other defence industries. The studies of dual-use technology, even though some focus on quite idiosyncratic factors, could be divided into four sections hypothesising general explanatory factors, and it is these that will be empirically reviewed in this thesis.

## 3.1 Dual-Use Technology

Defining the concept of dual-use technology is no clear-cut process. The literature on dual-use technology has relatively few articles that deal directly with the definition, which leads to a certain degree of obscurity. Moreover, there are other conceptual interpretations of defence–civilian spillovers that are closely tied to dual-use technology, but that could still not be considered as such. Terms like multi-use and single-use technologies have been studied in the same discourse, but are not the same, as the definition will show.

Nonetheless obscurity, it seems to exist a basic understanding of the concept 'dual-use technology'. Several of the articles and books reviewed by Acosta et al. (2011) as 'key papers on dual-use technology' (p. 337) briefly define the concept more or less in the same way. Thus, in a book that is one of the most cited among the publications, albeit the literature is not as vast, Alic and colleagues (1992) define dual-use technology as: 'Technology that has both military and commercial applications' (p. 4). More recent publications (Brandt, 1994; Cowan & Foray, 1995; Kulve & Smit, 2003; Molas-Gallart, 1997; 1998; Reppy, 1999; 2006; Smit, 2001; Stowsky, 2004) have broadened this definition to: technology that is developed and used by the military on the one hand and by the civilian sectors on the other. Further, a technology is understood as dual-use when it has current or potential civilian or military applications (Molas-Gallart, 1997; Stowsky, 2004).

Thus, scholars seem to have reached a general understanding of the concept, however, the obscurity becomes prevalent when one goes deeper into the concept of technology. Alic (1994, p. 158) notes that most technologies are in fact *multi-use*. Whereas, equipment such as machine tools could be used in manufacturing plants, and the technology's application of use will be the same whether the plant serves military or civilian markets. These technologies would be considered examples of multiple use rather than dual-use technologies (Alic, 1994, p. 158).

Some authors (Cowan & Foray, 1995, p. 852; Molas-Gallart, 1997, pp. 372–373; 1998, p. 5) have taken further steps to emphasise a clarification between multi-use and dual-use not dealt with by other scholars. Although multi-use could be viewed as inherent in the concept of dual-use technology, the term 'multi-use' does not imply that a technology is dual-use per se, since a multi-use technology could be transferred within and across units without any intention to change its application. This is an important aspect that sets the grounds for the understanding of dual-use technology in this thesis. Thus, when the technology is transferred across units for the same application there has been a transfer of technology, but not in the case of dual-use technology transfer, only multi-use (Molas-Gallart, 1997, p. 372). For example a laboratory may sell a licence for an infrared seeker component to another company that intends to use the technology for the same purpose (Molas-Gallart, 1998, p. 5). This is an example of transfer across economic units, not across purposes. Dual-use technology refers only to the case when there is an intention to change the initial (military or civilian) application of a technology. Therefore, multi-use technologies can become subsequent dual-use technologies, but only if the application is different from its origin. There are several examples where dual-use technology becomes present. One is discussed in Markusen and Yudken (1992, p. 213) where Kaman Aerospace, a US defence contractor applied its vibration reducing technology designed for helicopters to the production of high-end fiberglass-laminated acoustical guitars. Furthermore, when we think of technology, we often think of high-tech products such as super-computers or advanced laser-designated missiles, but dual-use technology does not only comprise to the artefacts themselves. Also the theoretical knowledge and practical know-how comprise the essence of technology. Thus the same computational techniques used to design a blast-resistant missile silo can be applied to the design of skyscrapers (Alic et al., 1992).

Some technologies are neither multi-use nor dual-use, but in fact *single-use*, such as stealth technology – this technology has very few, if any significance for civilian applications (Alic, 1994). However, it is often only at the final product stage where one observes little dual-use, not at the subsystem or components level (Cowan & Foray, 1995). For example, the stealth technology is of little use to civilian industry, but the fibre-reinforced composite structures that are a part of the stealth package, did prove significant in the construction of the civilian Beech's Starship aircraft (Alic et al., 1992, p. 42).

Cowan and Foray (1995) point out that the potential duality of a technology varies depending on the very nature of the technology, whether it be product or process technology as well in what phase of life. The authors stress that there are two factors determining the opportunity for dual-use of a technology. First, early in the lifecycle of a technology there are large gains to be had from the technology, when the technology is at a generic stage. Second, when the technology is a process technology the benefits of duality can be extricated later in the life cycle. In terms of the mentioned stealth technology, which is a product technology, little duality exists in the end product according to Alic and colleagues (1992). But early in the development of the aircraft the more generic technology on composite materials might have come to dual-use application in civilian industry.

On the other hand Molas-Gallart (1997) do not address the technology's lifecycle, but pays attention to the organisational background underlying the relationships between defence and civilian technologies, and how this might contribute to dual-use technology transfer. According to Molas-Gallart (1997) the concept of dual-use may convey a misleading image, placing military and civilian technologies as clearly defined, contrasting entities, with dual-use technologies taking a sort of middle ground. In reality, there is a diversity of military products with varying degrees of similarity with civilian goods, and a common base of generic technologies that can be indistinctively applied to military or civilian developments. There is no clear-cut distinction between civilian and military technologies, and the author therefore considers technology to be 'dual-use' when it has current or potential military and civilian applications.

As a brief backdrop on the definition of dual-use, there are evidently some unclear aspects of the concept. In this thesis I aim to take the definition of dual-use in a pragmatic manner. By that I will take all the different definitions into consideration, but with an emphasis on the clear-cut distinction of dual-use technology argued by Molas-Gallart (1997; 1998) and Cowan and Foray (1995): That one can only speak of dual-use technology when there is or has been an intention to change its initial application, whether civilian or military. By taking this definition in addition to the general understanding of the concept: 'technology that has both military and civilian applications' (Alic et al., 1992, p. 4), I will include the mentioned multi-use technology, but exclude the end-state of this, where there are no new use or new application of technology, only imitation.

### 3.1.1 Dual-use as a policy issue

Both the current and earlier uses of the concept of dual-use technology have been highly influenced by different policies. The term is not new, and has been employed under two contrasting perspectives. The phrase first appeared in modern policy discourse around 1948, when the Cold War was hardening (Reppy, 1999). From an arms control outlook, dual-use technology was seen as a problem for the control of the international diffusion of advanced weaponry. Particularly the United States struggled to develop a workable policy for controlling exports of military relevant goods to the former Soviet Union (Reppy, 2006).

Until the mid-1980s the concept was viewed as a problematic feature that complicated especially export controls (Kulve & Smit, 2003). Under this period, technologies developed originally for military purposes diffused from the defence industry into civilian industries, and spread thereafter. However, it was only in arms control policies that dual use was of concern. In other areas, dual-use technologies were seen as a positive side-effect of high R&D investments in defence industries that could influence civilian capabilities (Mowery, 2010). As Bitzinger (2003, p. 14) comments: '[…] armaments production was viewed as a 'technology locomotive' spurring the growth of new industries and technologies, particularly in aerospace, electronics and information technology'. Due largely to the heavy governmental investments in R&D by the US government, the US defence industry developed several radical and incremental innovations that spilled over to civilian applications (Alic, 1994; Alic et al., 1992; Cowan & Foray, 1995). The military technology was more advanced than the civilian, and therefore the military R&D was highly relevant to commercial industry (Cowan & Foray, 1995). Some authors (Avadikyan et al., 2005; Stowsky, 1992) have chosen to characterise this period as a 'spin-off paradigm', where dual-use technologies spread to civilian applications. The development of the semiconductors, telecommunication satellites, aircrafts and composite materials found its duality in the civilian sector, and was quickly adopted for other applications (Alic, 1994; Avadikyan et al., 2005).

By the mid-1980s there was a shift in the dual-use discourse, and especially the US Department of Defence adopted a policy in encouraging the use of commercial products for military programs (Reppy, 2006). By the end of the Cold War and the dissolution of the Soviet Union left the arms control regime for proliferation of dual-use technologies in disarray (Reppy, 1999). The understanding of the concept shifted to something that should be pursued since it might solve the problem of maintaining a high-tech defence technology base restrained by limited budgets (Kulve & Smit, 2003).

Meanwhile the innovation dynamics shifted towards the civilian sector, reversing the direction of the technological flow. From civilian to defence sectors – a shift that some authors describe as the 'spin-in paradigm' (Alic et al., 1992; Brandt, 1994). In reference to Stowsky (2004) the dawn of the information age created a dramatically different environment, in that most military equipment now derives from highly sophisticated commercial technology. The defence industry have not been able to keep up with the intense development and diffusion of technology, most due to stifling procurement procedures and the long lifecycles of defence systems (Molas-Gallart, 1997). Thus leaving them to lag behind in some sectors. Cowan and Foray (1995, p. 854) point out that several economists have argued that the importance of military R&D for civilian sector has declined significantly and that there is a reversal of roles.

Nowadays the discourse around the dual-use concept is prevalent in discussions concerning civilian science, in particular biotechnology. The concept has again assumed a more negative connotation, in the sense that technologies with legitimate civilian uses (e.g. drugs/vaccines) could be misappropriated to produce chemical or biological weapons (McLeish & Nightingale, 2007; Reppy, 2006). Still in the defence–civilian discourse, Micara (2012), Fuhrmann (2008), Mowery (2012), and Norwegian White Paper 38 on the defence industry (MoD, 2006) show that the discussions of defence–civilian spillovers of dual-use technologies are still highly relevant. Especially the white paper makes this current in a Norwegian context by emphasising the importance of promoting exchange of generic technologies both to and from the defence sector.

The specific focus of this thesis is not to inquire whether the dual-use technologies from the defence industrial base should generate concerns of arms control, but rather to study to what extent dual-use technologies spread to civilian sectors. Thus, potentially revealing inter-sectoral effects that could be supported by policy.

## 3.2 Extent of Defence–Civilian Spillovers

Alic and colleagues (1992) characterised the period from the end of the Second World War and the mid-1980s as spin-off paradigm of defence–civilian spillovers. The extent of dual-use technologies in this period has been emphasised by several authors as pertinent for this period (Avadikyan et al., 2005; Mowery, 2010; Bellais & Guichard, 2006). According to Avadikyan et al. (2005, p. 161) defence–civilian spillovers have often been seen as a result of military 'big programmes', whereas high investments in R&D have resulted in new radical innovations with inter-sectoral applications.

However, the means of measuring the extent or tracing the knowledge flows of defence–civilian spillovers has unfortunately been little explored in a quantitative sense, besides some studies that have used patents (Mowery, 2010, pp. 1234–1235). Because of this, most studies has questioned how and why these spillovers occur, and by such the main body of literature are case studies. Even so, evidence of dual-use technologies is found in studies of defence industries and specific defence enterprises in the US, France, the UK, and the Netherlands (Stowsky, 2004; James, 2000; Avadikyan et al., 2005; Kulve & Smit, 2003).

Nonetheless, Acosta et al. (2011) addressed these defence–civilian spillovers in a quantitative manner with patent analyses. As one of several conclusions, the authors note that the countries producing the most defence–civilian spillovers of dual-use technologies are British, French and US defence industries. Moreover, the US was reported as the country that made the greatest use of military technology for civilian purposes.

## 3.3 Explanatory Factors of Dual-Use

The main body of literature that has studied defence–civilian spillovers of dual-use technology have addressed numerous factors, which either inhibit or enable such spillovers. These explanatory factors could be divided into four main sections arguing how these spillovers come about: from external cooperation, technological breadth, innovative capabilities and civilian orientation. The sections emphasise these different and complex factors with each its hypothesised effect on spillover, which will constitute the theoretical basis for analyses. Meaning, whether these through both quantitative and qualitative approaches could explain the pattern of defence–civilian spillovers from the Norwegian defence industry, and to provide new empirical knowledge.

### 3.3.1 External cooperation

A part of the literature has emphasised the potential benefits of cooperating with external firms in defence developments. The aspects of avoiding cooperation especially with civilian firms could even be self-defeating in successfully developing new products or processes.

From case studies of technologies developed from the 1950s until the early 2000s, Stowsky (2004, p. 258) identified two distinct patterns of civilian–military interaction. One pattern, 'shared innovation', is described as where knowledge flows back and forth between companies in the defence industry and commercial enterprises. This approach embraces openness between both sectors, and is presumed by Stowsky to be the best way to ensure dual-use technology in the midst of a global, commercial and digital economy. Shared innovation is characterised as projects where foremost military investments in technological research aim at advancing a general technological capability, let commercial concerns drive the trajectory of development, and invite ideas from researchers and potential technology users from civilian sectors (Stowsky, 2004). Kulve and Smit (2003) show in their case study that collaboration between civilian and military actors played a significant role in the development a bipolar lead-acid battery. However, they do add that the collaborative traits they call 'joint development projects' (p. 968), and what Molas-Gallart (1997, p. 383) termed as 'external adaption' appears to be a strategy that may be very difficult to realise.

On the other hand, shielded innovation is an organisational approach that has proven to hamper both innovation of the technology itself, as well as the dual-use potential (Stowsky, 2004). The approach is characterised as where defence contractors target specific military applications for purely military needs, and where the flow of information both to and from is restricted. Such endorsement of secrecy has in fact not entailed any competitive advantage for the defence industry (Stowsky, 2004). Despite the efforts to shield the innovation process, commercial and more superior derived versions of the same underlying technology have still reached the commercial market (Stowsky, 2004). Shielded innovation, which is the other distinct pattern observed of civilian–military interaction does not contribute to dual-use technology. In fact, Stowsky found that of his case studies, two US shielded projects even failed to meet the military's own requirements, due to inadequacies of both sharing and absorbing knowledge. Avadikyan et al. (2005, p. 166) note that the need for secrecy is inherent in all military projects. Thus, the compromise of balancing the diffusion of knowledge, as well as withholding some is a great challenge.

*Hypothesis 1: Increased cooperation with external firms positively affects defence–civilian spillovers.*

This driver of dual-use technology is considered as a cooperative factor by that the more a defence firm cooperates with others, thus preferably civilian enterprises, the more technologies they potentially produce with dual-use applicability. However, Stowsky (2004) argued that if a defence firm works together only with military partners or keeps everything to themselves, there is a risk that dual-use technologies will not emerge, as well as of failure to develop purely military technologies.

Acquiring empirical data on this driver is potentially difficult, at least in terms of quantitative data, as the existence of such firm-level data is limited to a short time-period. Nevertheless, qualitative data might offer deeper insights into both the statistical results and the hypothesis.

### 3.3.2 Technological breadth

One driver of dual-use technology with a considerable technological character captures certain technologically specific aspects that have been found to affect dual-use technology. Inherent in this factor are also additional aspects in which the literature has discussed. Particularly how defence industries have become more apt to use civilian technology in their developments.

Several authors have argued the importance of the technological breadth inherent in a product by its effects of generating dual-use technologies (Avadikyan et al., 2005; Acosta et al., 2011). Avadikyan et al. (2005, p. 184) note that through the defence industry's application and combination of technologies from different sectors (e.g. aeronautics, materials, electronics and optics) several important product and process innovations have emerged. '[T]he ability within military projects to integrate diverse technologies, rooted in very different knowledge bases, in order to develop new products or systems, is one of the main sources of innovation diffusion' (Avadikyan et al., 2005, p. 165). Hall, Jaffe and Trajtenberg (2002) argue from analyses of patents, that patents with a great technological breadth could be considered general, and such patents may have particularly wide applications for further technological developments.

The assumption of technological breadth or variety is also addressed in Acosta et al. (2011) study. They discovered from their patent citation analysis that patents of a mixed technological origin received the most civilian citations. Furthermore, patents exclusively related to weapons were used less for civilian applications than those related to weapons and munitions, which in turn were used to a less extent than patents of both civilian and military origin.

Even though Acosta and his colleagues found support for their hypothesis on technological variety, some scholars have made important comments about defence industries and patenting. Bellais and Guichard (2006) argue that defence industries in general are quite sceptical to patenting. The act of secrecy, especially in defence industries, is due to that innovations of military value cannot be protected in the same way as those of economic value. Besides the obvious legal protection of a technology posed by the patent system, there exists a counterpart. By patenting, a firm reveals key information about a given technology, making it public and thereby risking misuse by others (Bellais & Guichard, 2006). In terms of defence technology aimed at providing strategic superiority, if potential enemies can access such information and then replicate it, this cannot be tolerated. That may explain the low rate of patenting by defence firms, particularly in the US (Lichtenberg, 1995) – but not in France (Guillou, Lazaric, Longhi & Rochhia, 2009, p. 178).

Technological breadth seems to also be affected by influences from civilian industries by that defence firms incorporate more and more generic technologies into the development of products and processes. Stowsky (2004) notes that the dawn of the digital information age has created a different environment of technological flow. In fact, during most of the Cold War era, defence firms strived to produce most technologies by themselves (Stowsky, 2004). Nowadays, with the development of many key technological areas such as electronics and ICTs, the pace of innovation led by civilian demand has outstripped parallel technological developments specifically targeted to the defence markets (Molas-Gallart & Sinclair, 1999). From that defence innovations used to be in the lead of 'spinoffs', to the current tendency that many civilian technologies now 'spin-in' to defence technologies does not mean that the technological relevance of defence innovations has declined (Reppy, 2006). Contrary, it means that by adopting civilian technologies in their developments the technologies gains further breadth as well as potential relevance to civilian sector. Thus the spin-in of technologies from the civilian to the defence sector favours the generation of incremental innovations and a potential feedback to civilian industry (Avadikyan et al., 2005). By that the defence industries adopts and improves the technologies, and adjust it to their use (e.g. for extreme environments, speed, reliability and discreteness). Thus, this spin-in process can in turn also create new innovation opportunities for succeeding civilian products by increasing the technological knowledge inherent in a product. This should introduce a strong potential for diffusion of dual-use technology (Avadikyan et al., 2005).

The white paper on the Norwegian defence industry (MoD, 2006, pp. 23–28) comment that there is an increasing spillover of knowledge from civilian to defence sectors, and that the industry should strive to adapt civilian technologies were the industry itself is not market leading in innovation. Such adaption is also perceived as to shortening the development of defence technologies. But more importantly, supplement the knowledge bases in developing technologies that might end up as dual-use.

*Hypothesis 2: Increased technological breadth positively affects defence–civilian spillovers.*

This specific driver is the only one that has received recent attention from both qualitative and quantitative studies through different means of measure. With this hypothesis it is interesting to study whether the technological breadth inherent in a technology has a greater potential of ending up as a dual-use technology in the civilian sector. Another aspects are if defence firms consciously combine many technologies in their development of new products in order to gain civilian interest.

### 3.3.3 Innovative capabilities

There are several firm specific capabilities that are known to affect innovation. Especially R&D has been shown to affect defence–civilian spillovers on the industrial level (Mowery, 2010). Moreover, the Norwegian defence industry is known to invest more than domestic industries and hold multiple advanced technological competencies.

However, writings on dual-use have addressed this factor only to a limited extent. Thus, only one publication on dual-use technology has explicitly attempted to reveal whether such could have an effect (Acosta et al., 2011). Others have discussed it rather loosely. Acosta and his colleagues (2011) inquired whether the technological experience, measured by patenting activity, of the patenting defence firm could have an effect on dual-use technologies. Their results were inconclusive.

Levin, Klevorick, Nelson and Winter (1987) argued in general that several firm specific capabilities would affect a firm's productivity and abilities to innovate. Thus, the Norwegian defence industry might not be any different since Mowery (2012) found that defence industry investments in R&D have influenced innovation in the broader civilian economy for several nations. In addition, several research papers refer to the Norwegian defence industry as highly innovative compared to other industries in the country (Fevolden et al., 2009; Castellacci & Fevolden, 2012). In general this is also a trait of other defence industries according to Mowery (2010). The Norwegian defence industry spends a large amount of their revenues on R&D in order to develop advanced products that could compete both domestically and internationally (Tvetbråten, 2011). Thus, one could assume that such investments in firm specific technological capabilities would generate a variety of technologies, whereas some are used by civilian industries, becoming dual-use technologies.

When it comes to generating new technologies, the two authors Cowan and Foray (1995) emphasised that technologies at this 'stage', have particularly good potentials of becoming dual-use. The authors point out that it seems that there is a greater potential for dual-use technology early in the lifecycle of a technology. Supposedly this is due to that many of the elements of a technology are of interest to both civilian and defence sectors. Especially the common interest of such technologies is emphasised in Verspagen and Loo's (1999) analysis of inter-sectoral technology spillovers. Whereas they found that there are profound tendencies of inter-industry spillover of technologies when a generic technology is similar to what another uses. One could therefore expect that industries with technological capabilities similar to those in the defence industry seek to adopt generic defence technologies. Both the case study by Kulve and Smit (2003, p. 967) and Reppy's article (1999, p. 276) seem to be in support of the Cowan and Foray's results (1995). Reppy notes that dual-use technologies are most likely to be found at the level of components, at a generic stage. Supplementing this is Mowery (2010, p. 1236), who points out that technology appears most significant in the early stages of development, and that a firm's technological capabilities is a decisive factor contributing to this. However, it seems that such capabilities in generating technologies lose some effect over time: as technologies mature, civilian and defence requirements frequently diverge, and civilian benefits decline (Mowery, 2012). Nevertheless, evidence of such exists only from qualitative studies, while results from quantitative studies remain elusive (Mowery, 2010, p. 1238).

*Hypothesis 3: Increased innovative capabilities positively affect defence–civilian spillovers.*

The particular technological capabilities of the defence industry are quite different from other domestic industries as Tvetbråten (2011) reports. Especially investments in R&D, with emphasis on the 'D' in development are a crucial factor for defence industries in general (Lichtenberg, 1995). However, there is little available firm-level data on such capabilities, which proved to be problem in Castellacci and Fevolden's study (2012) as well.

Moreover, a substantial amount of R&D investments are financed through public procurement schemes (Tvetbråten & Fevolden, 2011), and it has been suggested that public R&D might 'crowd out' private R&D spending (David, Hall, & Toole, 2000). Mowery (2010, p. 1238) comments this 'crowding out' aspect that public procurements increase military R&D investments, which could 'crowd out' privately financed R&D on technologies with potential civilian applications, and thus decrease the potentials of dual-use. However, the arguments on this seem to be rather suggestive than definitive (Mowery, 2010, p. 1239). The same is with qualitative studies (Mowery, 2010). Nevertheless, this leads to the next subsection, whereas it is assumed that increased gains from revenues of military sales might increase incentives to further deliver specific military systems, which could separate the defence industrial technology base further away from civilian relevance.

### 3.3.4 Civilian orientation

Defence firms that direct their technological developments towards mainly military customers will produce less technologies with spillover potentials compared to more heterogeneous firms with both military and civilian orientation.

David Mowery (2010) reviewed publications that dealt with the influence of military R&D and innovation across several nations. Particularly in the US, the defence firms that earned most of their revenues from selling specific defence systems tended to continue doing so, and thus continued to specialise in products for military use (Mowery, 2010, p. 1231). That is only logical. But by tracing the technological developments within a path that secures company revenues, these firms avoid the risks of developing technologies for new markets. Furthermore, over time such firms will produce products that almost certainly will generate fewer spillovers of knowledge into civilian applications (Mowery, 2010). This is evident for example in the military aircraft industry, where military demands have lead defence contractors to specialise within technological fields such as supersonic speed and stealth abilities (Brandt, 1994). These military specifications are very costly and have little civilian purpose, offering few incentives for civilian industries to adopt (Brandt, 1994). Thus, the factor is based upon that defence firms that achieve higher defence revenues are more oriented towards military markets, compared to those who achieve less. Defence-oriented firms produce fewer products with potential civilian applications than more heterogeneous firms with both civilian- and defence-related revenues.

The potential to favour purely military markets has led some defence firms into an institutional divide that Markusen and Yudken (1992) call ‘the wall of separation’. By that defence firms significantly diverge from the markets that civilian enterprises operate in, with many customers and competitors, as well as a vide variety of technological influences. This ultimately leads towards little industrial compatibility that inflicts the spread of dual-use technologies (Molas-Gallart, 1997). However, in another publication, Kelley and Watkins (1995) present contrasting arguments and criticise Markusen and Yudken (1992) for the lack of empirical evidence, and conclude from their analysis that the institutional barriers thought to separate defence contracting from commercial manufacturing are actually quite rare.

Nevertheless, no one has actually studied whether this might be the case of the Norwegian defence industry. According to Tvetbråten (2011) the Norwegian defence industry is in large parts devoted to international export markets, and their revenue of sales in 2010 was over 14.2 billion NOK. This revenue consists by sales of products that might have both civilian and military applications (Tvetbråten, 2011, p. 10).

This factor assumes that the more a defence firm is orientated towards serving civilian markets, the increased relevance the developed technologies will be, thus generating defence–civilian spillovers. The more a defence firm achieves of defence revenues, the less will they focus on civilian markets, thereby producing spillovers to civilian industries. This because they end up producing very user-specific products intended for military application. Furthermore, increased defence-related revenues might also invoke increased incentives for cooperation with only military clients. As noted in connection with the cooperative factor above, Stowsky (2004) discovered through his case studies that such cooperation strategies where the intention is to develop technologies for very specialised military equipment might result in less potential dual-use technologies.

*Hypothesis 4: Increased civilian orientation positively affects defence–civilian spillovers.*

In the former factor on innovative capabilities it became clear that the empirical data available for testing such a hypothesis are limited by the quantitative firm-level data available. That is also the case with this hypothesis. Nevertheless, the quantitative data will give a good indication of this by the measure of defence revenues. Thus, increased defence revenues indicate less civilian orientation, and should negatively affect spillovers. Moreover, the qualitative approach will attempt do give support and try to bridge other perspectives of this factor.

## 3.4 Concluding Remarks

The concept of dual-use technology has been influenced by both policies and various interpretations. Nonetheless I have attempted to narrow all the different meanings into one clear definition of the concept: that one can only speak of dual-use technology when there is or has been an intention to change its initial application, whether civilian or military (Cowan and Foray, 1995; Molas-Gallart, 1997; 1998). Moreover, by taking this definition in addition to the general understanding of the concept 'technology that has both military and civilian applications' (Alic et al., 1992, p. 4), I will include the previously mentioned multi-use technology, but exclude the end-state of this, where there are no new use or new application of technology, only imitation.

Dual-use technology has been studied as both a defence–civilian and a civilian-defence spillover. These two directions of dual–use spillovers have been termed as two spillover paradigms, spin-off and spin-on. The thesis will direct its view upon the defence–civilian spillovers of technology, by studying the flow of dual-use technologies from the Norwegian defence industry to civilian applications.

Publications on defence–civilian spillovers have shown that there is limited knowledge on the extent of such at the industry level. Even though studies of both defence industries and defence firms in other nations have shown numerous examples of influential defence–civilian spillovers of dual-use technology. Moreover, most studies have questioned why and how such spillovers occur, rather than to what extent. Nonetheless, a recent publication addressed this by quantitative means and proved that the use of patent data as an indicator of spillovers is in fact adequate (see Acosta et al., 2011). The task of revealing to what is the extent of defence–civilian spillovers from the Norwegian defence industry to civilian sectors, forms the first research question.

The main body of literature discusses several explanatory factors for such spillovers. External cooperation, technological breadth, innovative capabilities, and civilian orientation, are all hypothesised to affect dual-use technologies. These explanatory factors constitute the theoretical basis for the second research questions, and will be empirically reviewed through both statistical analysis and interviews. In figure 3.1 below the factors are conceptualised, with each a hypothesised effect on dual-use technology.

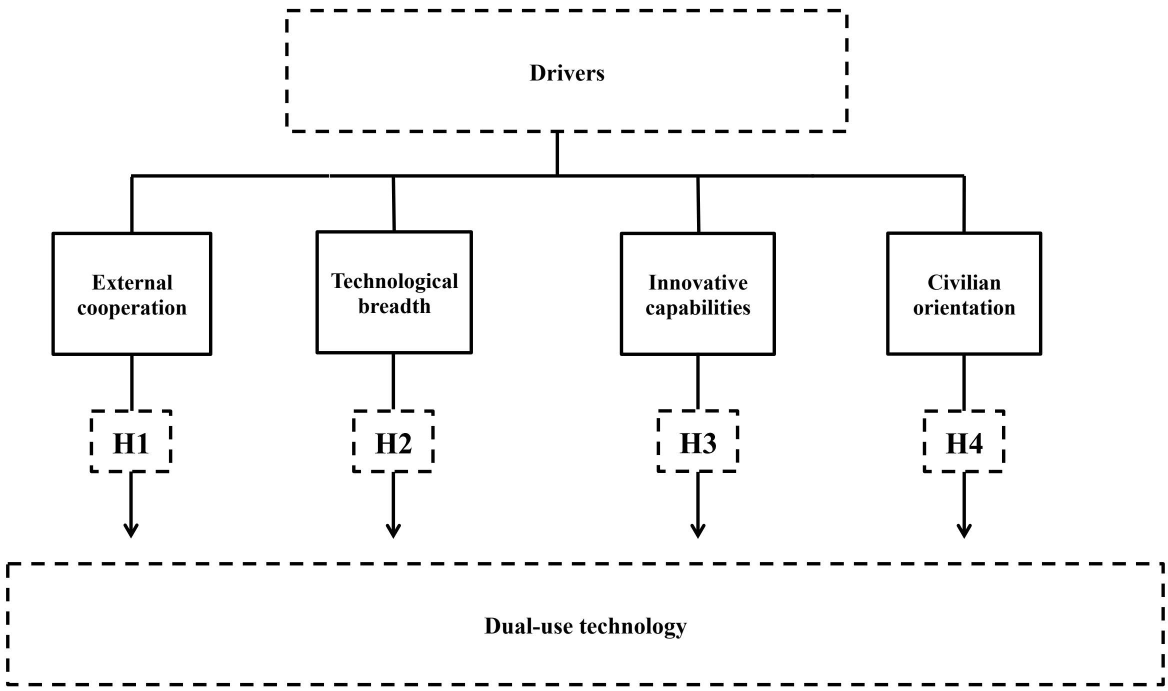


**Figure 3.1** The drivers of dual-use, represented as hypotheses.

# 4. Methodology and Data

The methodological approach to the research questions is by the application of mixed methods, which combines both quantitative and qualitative data collection and analyses. Throughout the empirical process all the methodological decisions taken has been kept with a research diary (Dowling, 2010, p. 31). This has been done with the intention of assessing the on-going methodological steps, but also to offer transparency to the reader by thoroughly discussing the validity and reliability of this thesis.

This chapter will present the process of preparation, collection and analyses of both the quantitative and qualitative data. First, the approach to the research design and the mixed methods will be clarified.

## 4.1 Why Mixed Methods?

The research design taken in this thesis is of what is known as mixed methods. This approach combines both qualitative and quantitative methods to a variety of utilisations (Kvale, 2007, p. 46). The intention is more than collecting and analysing both types of data, it also involves the use of both methods so that the overall strength of a study is greater than singularly qualitative or quantitative research (Creswell, 2009, p. 4; 203).

Mixed method strategies are less well known than quantitative or qualitative approaches, and are relatively unchartered in the research domain (Creswell, 2009, p. 14; McCracken, 1988, p. 29). Nevertheless, this methodological approach has seen some attention during the last years (Creswell, 2009, p. 204). Even though the field is still debated on both practical and philosophical levels, several researchers have implemented it in studies of social science, and there are journals specialising in the discussion (e.g. Journal of Mixed Methods Research[5]; Quality and Quantity[6]). Creswell (2009, p. 3) and Punch (2005, p. 234) hold that qualitative and quantitative approaches should not be perceived as opposites, but as different ends on a continuum. Thus, mixed-methods research is located in the middle of this, because it includes elements from both approaches, in order to broaden the understanding by incorporating both qualitative and quantitative research, or by using one approach to better understand, explain, or build on the results from the other approach (Creswell, 2009, p. 205;

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[5] *Journal of Mixed Methods Research* - http://mmr.sagepub.com
[6] *Quality and Quantity* - http://link.springer.com/journal/11135

Iversen, 2011, p. 175). In terms of research design, mixed method has adopted three general strategies for research: sequential, concurrent, and transformative (Creswell, 2009, pp. 14–15).

This thesis has, with the combination of patent citation analysis and semi-structured interviews, chosen a sequential explanatory strategy (Creswell, 2009, p. 211). A sequential explanatory strategy is commonly used with quantitative methods first, whereas significant results or outliers condition further research through qualitative approaches.

However, according to Creswell, Clark, Gutmann & Hanson (2003, p. 227) the strategy could also be used as I intend, so that the quantitative approach also guide the sampling of respondents. Moreover, the qualitative results will contribute in supporting the statistical results, as well as providing a qualitative perspective. Employing quantitative methods first can reveal the prevalence of dual-use technology from the defence industry, which will indicate to what extent civilian usage of military technology can be observed, as measured by citations. Further, by not only testing the hypotheses of dual-use technology (see chapter 3), this will also reveal certain firms and relevant characteristics that can provide a purposeful sampling of respondents for the interviews. This type of approach has also been emphasised as advantageous for future research in a seminal research string on patent citations by Jaffe and his colleagues (Jaffe, Trajtenberg & Henderson, 1993; Jaffe, Fogarty & Banks, 1998; Jaffe, Trajtenberg & Fogarty, 2002).

The research questions functions as a lens for the whole study. These will first be inquired through descriptive analyses and regressions. Then, the qualitative approach will take advantage of the descriptive results from the patent analysis in order to select the most spillover producing companies. Through the interviews the research questions will be addressed qualitatively, which will both support and deepen the interpretation of the quantitative results. This two-phased project treats the two approaches equally, which is straightforward and by such a popular strategy (Creswell, 2009, p. 211). Another advantage is that the results can be reported in two phases with a final discussion bringing the results together.

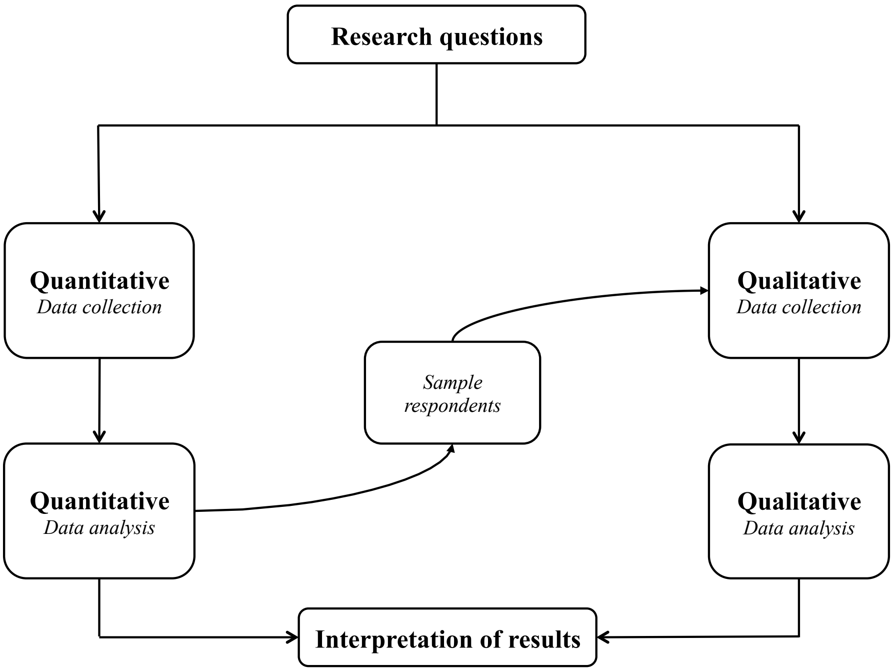


**Figure 4.1** The mixed method research design of the thesis.

## 4.2 Quantitative Approach

The quantitative approach includes the use of defence patents, subsequent citations and firm-level data. The data provide the empirical foundation for statistical analyses that seek to elucidate the research questions. This section will present the process of collection and the approaches to analyses, thus offering repeatability. First, the steps of collecting the data are presented, followed by subsections showing the dataset variables and how these are used in the statistical analyses.

### 4.2.1 Data collection

The collection of quantitative data involved both a theoretical evaluation of earlier approaches that have studied defence–civilian spillovers, but also those that have studied the economic effects of inter-sectoral knowledge spillovers. Furthermore, to ensure a certain rigour of the empirical data, the process also involved an extensive verification process.

The literature review on the concept of dual-use technology revealed several approaches to studying the concept. Many of these publications have employed qualitative methods of inquiry. However some have chosen to see whether quantitative grips might shed new light on the concept. Thus, the decision to collect patent data in order to measure the extent of defence–civilian spillovers of dual-use technologies from the Norwegian defence industry was mostly inspired by a recent publication, hence Acosta et al. (2011). In their study Acosta and his colleagues collected defence originated patents and subsequent citations of the former. Throughout analyses, they argued that patent citations give a good indication of the spread of dual-use technologies from the defence industries to civilian-sector applications. Thus, in contrast to many earlier publications on dual-use, they demonstrated alternative measures of assessing dual-use technology by implementing publicly available patents in quantitative analysis.

However, there are some disadvantages by using patents for studying dual-use technology: not all knowledge flows are captured by patent citations, since knowledge can be tacit and not only codified (Acosta et al., 2011, p. 338). In addition, not all inventions are patented (Kleinknecht, Montfort & Brouwer, 2002; Smith, 2005[7]). Griliches (1990, p. 1702) emphasise that: '[i]n spite of all the difficulties, patents statistics remain a unique resource for the analysis of the process of technical change'. Nevertheless, Granstrand (2005) point out that the effects of the patent system in general varies to great extent over nations, industries and enterprises. This fact, hence the propensity to patent, seems to vary in a large extent across these entities. In the seminal study by Levin et al. (1987, p. 817) the authors point out that firms have quite varying views on patenting in terms of appropriability. The propensity to patent is also an issue that arises in this thesis, and is an aspect that will be empirically reviewed and discussed later on.

### 4.2.2 Patents

Defence patents from the Norwegian defence industry were collected to form the basis of analyses, as it were these that subsequent patents would cite. With the defence patents collected these would together with the citations indicate defence–civilian spillovers of dual-use technology. Moreover, the defence patents would also indicate which firms and defence technologies that are most apt to produce spillovers.

Since the case of this study is the Norwegian defence industry, I could not limit the

[7] Keith Smith discusses a variety of ways to measure innovation. The analysis of patents are only one of those, nonetheless, its use has proven to be fruitful (Smith, 2005, p. 160).

selection of patents to inventions on weapons and munitions as Acosta et al. (2011) did. Since this would leave me with to few observations, and subsequently to few citing patent applications of civilian art. Acosta et al. (2011) collected patents on munitions and weapons from all major patent databases, and found 582 inventions – which is not that many, considering that there are more than 70 million patents worldwide (Espacenet, 2011). Therefore, I chose to search up all applied patents from each of the firms in the Norwegian defence industry and download the available data on each patent. Each firm search was attempted with different uses of company names, in order to take into account potential typing errors made by the patent officer. This extensive collection of patents was conducted through the Norwegian Industrial Property Office's search engine (2012). The data collected on a excel sheet included all the available information on the front page[8] of the application file, consistent with Jaffe and Trajtenberg's (2002, p. 3) recommendations.

The firms classified as Norwegian defence firms consisted of 100 firms selected in accordance to the definition described in chapter 2[9] (see appendix 1 for full list). All patents were collected, no matter whether they had expired, were pending, granted, withdrawn, or shelved. This is because the information on each patent had been made public and therefore had a potential of receiving subsequent citations. Several of the 320 patents found were intended for civilian purposes and not only military ones. This is a consequence of the fact that many of the firms are very heterogeneous, and are involved in civilian industries as well. Thus, I had to remove all civilian-related patents. This was done by going into detail on every single patent, reading their detailed description, viewing their technological classification (see next subsection), and sometimes even searching the firm, technology, and the patent characteristics on Google. Since patents are public this often revealed press releases by the firm or a buyer of that technology, hence giving grounds to determine whether the invention was intended for military or civilian use. This process resulted in a set of military defence industrial patents consisting of 139 patents in total, distributed over a time period of 41 years from 1970 until 2011.

[8] See appendix 2, Figure 2.1 for an example of a patent search.
[9] Note: as commented in chapter 2, it is particularly difficult to classify firms into the Norwegian defence industry. The number of firms that qualifies as defence firms varies continuously. Thus, it might be that some of the firms today could no longer be considered as defence firms by that they have gone into other industries due to mergers or strategic decisions, or have gone out of business. Moreover, new firms might also have come about.

### 4.2.3 Citations

The collection of patent citations was done, as these are technological inventions that are based upon the previously mentioned defence patents. Citations in general indicate technological spillovers, but civilian citations indicate defence–civilian spillovers. These citations function as to serve the statistical analysis in inquiring the extent of dual-use, as well as to test whether the explanatory factors affect the occurrence of these citations.

Patent citations have received increased attention in the literature compared to patent counts that have long been used as a indicator of innovation (Maurseth & Verspagen, 2002; Griliches, 1990). Receiving citations is often considered as Hall and colleagues (2002, pp. 417–418) comment it:

> [I]f patent *B* cites patent *A*, it implies that patent *A* represents a piece of previously existing knowledge upon which patent *B* builds, and over which *B* cannot have a claim. […] [T]he fact that patent *B* cites patent *A* may indicate knowledge flowing from *A* to *B*. Second, citations *received* may be telling of the importance of the cited patent.

Since a citing patent cannot be the same invention, imitation or the previously mentioned multi-use aspect of a technology is avoided (chapter 3). Thus, a citation could be used as an indication of new application of a previous technology, hence potentially dual-use. This interpretation is also adopted in Acosta et al. (2011) study.

In addition, the use of patent citations ensures some validity of that the citation is just, and not as a consequence of random citations. This is because both the applicant and the patent examiner are legally obliged to cite previous patents upon which inventions the patent holds (Trajtenberg, 1990, p. 174; Griliches, 1990, p. 1689). Hence, leaving a 'paper-trail' (Jaffe et al., 1993, p. 578). Nevertheless, this paper trail might be constrained by time. Thus, as time moves closer to the last patented technology in the dataset, the number of observations decreases (Hall et al., 2002, p. 410; Carpenter, Narin & Woolf, 1981, p. 161). This lag between the citing and the cited patent therefore poses what is known as a potential 'truncation bias' (Trajtenberg, 1990, p. 186), and is thus important to consider in any regression.

In collaboration with the project (see acknowledgements), subsequent citations were procured from the Norwegian Industrial Property Office on the basis of the collected defence patents. The intention was to see whether the military patents had received subsequent citations, thus an indication of knowledge flow (Nelson, 2009).

The procured citations when received from the property office consisted of 688 citations. Whereas I started the process of searching up and verifying every patent citation using the worldwide search engine at the website of the European Patent Office website, Espacenet (2012)[10]. As with the defence industrial patents that were verified as military technology. This process of verifying the citations as civilian or not were in fact quintessential to the thesis. By verifying each citation I could assume that a civilian citation of a military patent was in fact a civilian application based on prior military technology, and thus an indication of dual-use technology[11]. During this examination I followed several criteria for selecting civilian patent citations, as well as plotting in all interesting characteristics of the citations (these characteristics will be explained in the subsection on variables below). The criterion for a valid civilian citation was: first, that it is not military, second that it is not a self-citation, and last whether essential information was missing.

Looking at a citation as displayed through the Espacenet search engine, there is no academic consensus on how to determine to which industry it is affiliated – especially if one is seeking to identify military industries. Thus my approach was to categorise the citations into technological fields by thoroughly reviewing its international patent classification (IPC) code and the written document. This was done by using a technology concordance table developed by Schmoch (2008) that is continually updated on the website of the World Intellectual Property Organisation (WIPO, 2011; see also appendix 3 for Table 3.1)[12,13].

Patents that were coded as non-civilian citations were military inventions that had IPC codes for weapons and/or munitions (class: F41 and/or F42), or some description about its field of use that could indicate military application. Second, citations that were self-citations, meaning: citations where the citing and cited patent is assigned to the same corporate organisation or inventor were also coded as non-civilian[14] (Jaffe & Trajtenberg, 1999). Finally, citations with missing IPC codes, no description, or no company name were then discarded from the whole dataset. In sum, this validation left me with 679 citations, where 392 were coded as valid civilian citations and 287 as non-civilian (111 military and 176 self-citations).

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[10] The same procedure was done in Maurseth and Svensson (2012). See example of patent search in appendix 2, Figure 2.2.

[11] This process of verification of civilian user-sector was not done in Acosta et al. (2011). Thus, their 'civilian citations' may not actually be civilian.

[12] Hall et al. (2002, pp. 452-454) employed such a table, but one that was based on the US Patent and Trademark Office's (USPTO) classification system.

[13] Breschi, Lissoni and Malerba (2004, p. 73; 89) employed the same approach as this thesis by categorising technologies based on IPC's.

[14] Jaffe and Trajtenberg (1999) defined self-citation only in terms of patents assigned to the same corporate entity. By that I have also checked for inventors might invoke some validity. However, it might not be enough as the authors comment on their own approach: '[t]his almost certainly understates the extent of self-citation' (p. 113).

All citing patents were applied throughout a period of 38 years, from 1974 until 2012. Figure 4.2 shows the structure of the data.

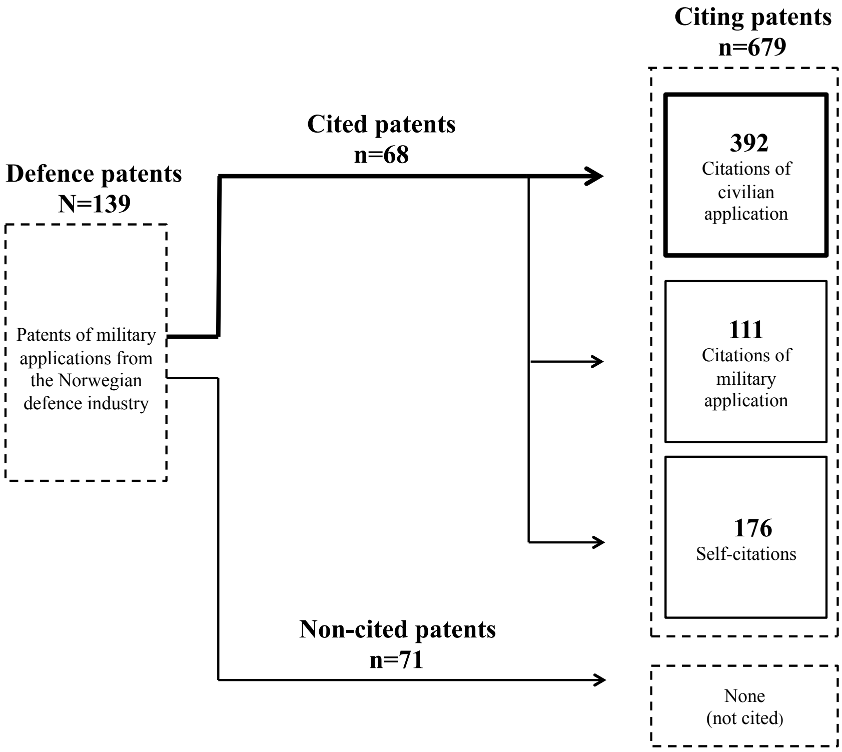



**Figure 4.2** Structure of the data

## 4.2.4 Firm-level data

To supplement the collected patent data, I acquired firm-level data on the companies in the defence industry. These help to give more detailed variables, supplementing the statistical analysis of the hypothesised explanatory factors.

Many of the publications on dual-use technology have made assumptions about how dual-use technologies from defence industries come about. However, apparently few have actually explored whether certain firm specific capabilities might have an influence on this. In the subsections above (3.3.1, 3.3.3, and 3.3.4) I discussed several firm-specific capabilities, whereas some stand out in the Norwegian defence industry compared to other domestic industries (see also chapter on context). However, in order to examine these through quantitative measures, and to test the hypotheses appropriately, I had to find other sources of information, as patent data are quite technologically oriented.

Thus, I borrowed two datasets collected by the Norwegian Defence Research

Establishment, that capture detailed firm-level characteristics. These were: account data on Norwegian defence firms, and the results from the VIFIN-survey[15]. The survey revealed several potential variables that refer to the year of 2006, but due to little variance among the values many were omitted besides three. The account data collected from the defence industry, referring to the year 2009,[16] yielded some interesting variables enabling the inquiry of firm capabilities such as: market orientation and innovative capabilities. Even if this supplements the patent data, it is important notice to that these data have been collected in different periods. Ideally, the firm-level data should have been panel data, which could have matched the patent data by year. However, such extensive datasets are not available, and this could entail some weakness in the dataset of this thesis.

### 4.2.5 Variables

The variables in the dataset have been included to answer the research questions. With the collected empirical data this is done by both descriptive statistics and regressions. The variables are therefore presented in two subsections below according to their purpose. Construction of the variables for the dataset has followed mainly the descriptive instructions in Hall et al. (2002, pp. 407–409), and the methodology discussions in Acosta et al. (2011).

The dependent variable that functions as the proxy for defence–civilian spillovers, is the variable called *CIVCIT*, or civilian citation, in table 4.1 below. The variable is used as an indicator for the descriptive statistics, and as the dependent variable in the regressions. The dependent dichotomous variable is represented binary, by giving a valid civilian citation 1, and 0 otherwise. This dependent has been chosen because the first research question (see *i*) of this thesis is to inquire to what extent defence–civilian spillovers of dual-use technologies from the Norwegian defence industrial base can be observed. Thus subsequent explanatory variables are tested upon this indicator to see whether they affect the occurrence of a civilian citation, thus the value of 1.

Moreover, Hall et al. (2002, p. 418) have noted that the number of citations could indicate the importance of a patent compared to those who receive fewer or no citations. In addition, Acosta et al. (2011, p. 342) set the same dependent variable as this thesis, with the similar interpretation of it, as a proxy for defence–civilian spillover of a dual-use technology.

[15] The VIFIN-study is commented in the chapter 2, subsection 2.2.
[16] The account data were later published in an FFI report (Tvetbråten & Fevolden, 2011).

| Denotation | Description | Purpose |
|---|---|---|
| *CPAT* | Citing patent | Descriptive |
| *CTECCL* | Main technological class of the citing patent | Descriptive |
| *CAPPYE* | Year of the citing patent | Descriptive |
| *CAPPDA* | Date (dd.mm.yyyy) of the citing patent | Descriptive |
| *CNAT* | Nationality of the patentee | Descriptive |
| *CLAG* | Amount of time elapsed. Lag of years between the citing and the cited patent | Control |
| *SELCID* | Dummy variable which equals 1 if the citation is a self-citation, and 0 otherwise (see definition subsection 4.2.3) | Descriptive |
| *DINT* | International patentee. Dummy variable that equals 1 if the nationality of the patentee is international, and 0 otherwise. | Control |
| *CIVCIT* | Dichotomous dependent variable that determines the civilian or non-civilian use of military technology. Valid civilian citations give the value of 1, while all others (military and self-citing patents) give the value of 0 | Dependent |
| *PAT* | Cited patent | Descriptive |
| *PFIRM* | Cited defence firm | Descriptive |
| *PAPPYE* | Year of the cited patent | Descriptive |
| *PAPPDA* | Date (dd.mm.yyyy) of the cited patent | Descriptive |
| *PTECCL* | Main technological class of the cited patent | Descriptive |
| *PTECVA* | Technological variety, i.e. number of IPC-codes noted within each patent document | H2 |
| *DEFREV* | Defence revenue as a share of total revenue, measured in%. | H4 |
| *LPTOT* | Total labour productivity. Total revenue divided by total employment. | H3 |
| *RDINT* | R&D intensity. Total R&D as a share of total employment | H3 |
| *COOPEXP* | Importance of cooperation with export clients. Degree of importance: 1 = little, 2 = some, 3 = moderate, 4 = great. | H1 |
| *COOPDOM* | Importance of cooperation with domestic clients. Degree of importance: 1 = little, 2 = some, 3 = moderate, 4 = great. | H1 |
| *COOPCIV* | Importance of cooperation with civilian clients. Degree of importance: 1 = little, 2 = some, 3 = moderate, 4 = great. | H1 |

**Table 4.1** Dependent and explanatory variables

### 4.2.5.1 Descriptive analysis

Shown in table 4.1 above are several variables set with a descriptive purpose. The purpose is to answer the first research question, to what extent spillovers can be observed, but also to show the different distributions of these defence–civilian spillovers, accordingly: the basis of military patenting activity, citations over time, the technological distributions of the civilian citations, and the nationality of those. The means of computing the descriptive statistics is by the use of graphs available in the statistical program[17].

First and foremost, the variables used to compute the basis for the analysis and to show the military patenting activity over time from the defence industry are *PAPPDA* and *PAPPYE*. The first variable is to identify the military patent's application date and is used to

[17] This thesis has used SPSS v.19 for OSX 10.8.2.

identify the specific date of publication[18]. Moreover, the next variable that is the year of the citing patent, and has been set as years and not as date. This with an additional purpose recommended by Hall et al. (2002, p. 409), in order easily compute citation lags and trend descriptive data.

Secondly, to give an overview of what type of technologies the Norwegian defence industry has patented, the next variable used is *PTECCL*. This variable captures each military patents main technological class. The variable represents the technological class of a military patent, and has not only been set to show the technological distribution. But also to explore the most cited technologies, which will influence the sampling for the interviews. As noted in the subsection above (4.2.3), the technological classes were set on each citing and cited patent by utilising the technology concordance table (see Schmoch, 2008, p. 10; WIPO, 2011). This process proved to be strenuous, as I had to read through several hundred patent documents to decide which type of technological field was involved. Thus, it is possible that some inventions have been categorised incorrectly.

To show the defence–civilian spillovers, indicated by the citations, several variables have been used. These graphically display the extent of civilian, military, and self-citations over time. First, two variables have been used to distribute all of the citations according to which year they were published. These variables are *CAPPDA* and *CAPPYE*, and has the same denotation as the two first variables addressed above. Secondly, in order to differentiate between military, civilian, and self-citations, two additional variables were used. The dependent variable *CIVCIT* separates out civilian citations from military and self-citations. *SELCID* is therefore a dummy used to differentiate between military and self-citations.

Among the civilian citations that are an indication of defence–civilian spillovers, another variable is used to show the distribution of the main technological fields. This descriptive statistic will show in which technological fields the civilian citations are patented within, thus showing where military technologies have been used for civilian applications. The variable *CTECCL* is coded in the same way as the technological variable above on military patents (i.e. the technological concordance table).

Of the defence–civilian spillovers, *CNAT* is used to display graphically the international distribution of the civilian citations. The country origin on each citation was identified through the worldwide search on Espacenet (2012; see also appendix 2, Table 2.2). The descriptive statistics indicate in which countries military technology from the defence

[18] When search results yielded more than one application date, the earliest was chosen.

industry is used in for civilian applications. The country distribution is also used in the regressions, as the international distribution is substantial compared to domestic citations.

In addition to the former variables used for computing descriptive statistics, some have been mainly used to identify individual defence patents or citations. Thus, enabling later search and a more detailed review of a patent, if it receives many citations or are commented in the interviews. *CPAT* and *PAT* are variables that identify a patent in the dataset. The variables are represented by a unique value, which is a combination of numbers and letters ranging from 8 to 12 units.

As noted, a military patents technological class (*PTECCL*) was one of two variables used to sample out the technological fields that received most civilian citations on average. Together with the variable *PFIRM*, that is the name of the patenting defence firm, these two variables are used to compute number of civilian citations received on average. This functions as to sample out the most dual-use-producing defence firms of the industry, which is decisive for selecting respondents for interviews.

#### 4.2.5.2 Regressions

To answer the second research question, what factors could explain the pattern of defence-civilian spillover several variables are employed. These variables test whether the hypothesised explanatory factors could explain the spillovers of dual-use technology from the Norwegian defence industry. The explanatory variables are all included into the regressions. However, due to that some of these measure fairly similar aspects and risk producing multicollinear results, six regressions have been employed. Nonetheless, the regressions test whether the following factors matter for spillover: external cooperation, technological breadth, innovative capabilities, and civilian orientation.

The type of regression used in this thesis is binary logistic regression (Field, 2009; Tabachnick & Fidell, 2007). This is because the dependent variable is *CIVCIT,* or a civilian citation. This variable holds a binary nature, whereas a civil citation is given 1, and 0 otherwise. Moreover, the structure of the dataset has a grouped characteristic, meaning that the characteristics of the cited patent hold the same value for several of the citations. This is because there are far more citations than original defence patents. Furthermore, Acosta et al. (2011) is the only article addressing dual-use through the measure of patents. Thus I have attempted to address the dependent variable in the same manner.

To test hypothesis 1, whether cooperation with other firms affect defence–civilian spillovers, three variables from the VIFIN survey are used. All the explanatory variables are response results from the survey, capturing different aspects of cooperation. The variables are assumed to show a positive coefficient to civilian citation, hence affecting dual-use technology. *COOPEXP* seeks explain that the more a defence firm values cooperation with others, specifically export clients, should be positively related to civilian citations. *COOPCIV* seek to inquire the effect of cooperating with civilian clients, and *COOPDOM* with domestic clients. These three variables are all categorical variables ranging from 1 (little) to 5 (great), which have asked about the valued importance of cooperating with clients (export, domestic, and civilian). Moreover, as these variables measure quite similar aspects they are used in different regressions to avoid multicollinearity.

Hypothesis 2, examines whether technological breadth will affect spillovers. The hypothesis is tested with the explanatory variable *PTECVA*. The numeric value of this variable was set by counting the number of IPC codes, hence technological fields of reference, imbedded in an invention, and it ranges from 1 to 10. Thus, an increase of one unit, a reference, is assumed to increase the technological breadth of a technology, which should positively affect spillover.

To test hypothesis 3, if increased innovative capabilities of a defence firm affect spillovers of dual-use technology, two additional variables are used. These variables have been extracted from the account data borrowed from FFI. The first variable is *LPTOT*, or total labour productivity of a defence firm, which is the total revenue divided by total employment. The second variable is *RDINT* or R&D intensity, which is measured as: total R&D as a share of total employment. The same is with these two variables as with those testing hypothesis 1. R&D intensity and labour productivity measures similar innovative aspects of a firm, and cannot be included in the same regressions together. However, these need to be included with the other cooperation variables, thus giving the statistical analysis six regressions.

The last explanatory factor, hypothesis 4, is also tested with a variable from the account data. *DEFREV* is a variable that captures the defence revenues of each defence firm. Thus, a negative and significant result will support the hypothesis. Since increased defence revenues reduces a firm's civilian orientation, and increased civilian orientation is assumed to positively affect defence–civilian spillovers.

The two last variables are used as controls. I remarked under one variable (*CNAT*) above that the international distribution of citations was substantial compared to domestic citations. Of such, all regressions are included with a dummy variable (*DINT*) controlling for international citations. Moreover, in section 4.2.3 I noted how some scholars have warned about the possibility of truncation in using patent data. The amount of time a patent is publically available will affect the number of citations it receives (Jaffe & Trajtenberg, 1999, p. 109). Hence, as one stops collecting citations for a dataset, new citations will continue to come in after that. If this amount of un-discovered citations is significant, then the data suffer what is known as a truncation bias. To control for this I have constructed a variable denoted as *CLAG.* This variable indicates the time it has taken, by years, for each citation to cite the original patent.

All six regressions are computed with binary logistic regressions. This type of regression does not only serve to test the dependent properly, but it is also known be flexible compared to other techniques (Tabachnick & Fidell, 2007). Logistic regression takes no assumptions about the distributions of the predictor variables, hence, the predictors does not have to be normally distributed, linearly related nor of equal variance within each group such as in linear regressions (Tabachnick & Fidell, 2007, p. 437).

'Forced Entry Method' is the specific regression technique which has been used (Field, 2009, p. 271; Tabachnick & Fidell, 2007, p. 454). The technique is the method of choice for this analysis whereas all the predictors are placed into the regression models in one block. The choice of this technique is mainly based by that this approach is recommended in testing theory, and that other stepwise or sequential methods are often criticised for potential suppressor effects which might potentially result in a Type II error (Field, 2009, p. 272). Hence, wrongfully accepting the null hypothesis (Tabachnick & Fidell, 2007, pp. 454–456). Nevertheless, the direct method also poses some difficulties if the predictors are correlated, by that a predictor may show little predictive capability in the presence of other predictors.

## 4.3 Qualitative Approach

The qualitative inquiry does as the quantitative approach by seeking to answer the research questions. However, both the process of selecting respondents, conducting interviews, and analysing the information is very different than the former approach. The first subsection will discuss the choice of respondents, and the next subsection will present the specifics of the interviews. Finally, the last subsection clarifies the process of analysis.

### 4.3.1 Choice of respondents

The choice of respondents for the qualitative approach is based upon a sampling of the most dual-use-producing defence firms from the Norwegian defence industry. Which in addition to producing spillovers, also have their main technological competencies within the most cited technological fields. However, the choice of respondents did not only involve sampling of defence firms, but also which key individuals I should interview.

Traditionally in interviews it is common to select informants through a variety of ways (Punch, 2005, p. 187). However, most often the method of sampling is argued quite fluctuant with the term ‘purposive sampling’, which translates as a purposeful sampling (Punch, 2005, p. 187). Nevertheless, there are no simple strategies of sampling in qualitative methods due to the vast variety of approaches. Thus, in this thesis I have also taken a course of sampling the respondents in a purposeful manner.

However purposeful, the sampling has been conducted in a specific way. As noted, the sampling derived from the initial results of the patent citation analysis. The reason for selecting the most cited firms is, as Jaffe et al. (1998) explain: ‘[the] quantity of citations to a patent is a valid indicator of an invention’s importance’ (p. 198). The descriptive statistics revealed which defence firms and technologies that had received the most civilian citations (measured by mean)[19]. This process left me with six defence firms. The descriptive statistics computed on the most cited technological fields left eight technological fields. As will be shown in table 4.2, the firms that were interviewed had patented evenly in all these fields of technology.

Now that the specific firms of interest as well as technological fields were gathered I had to find whom I should contact within each firm. Thus, the specific criteria for selection of interviewees were: representatives with ingoing knowledge from the *most* civilian cited defence firms, which produced the *most* cited technological fields. Thus by requesting interviews of key strategic personnel at each firm I could conduct semi-structured interviews that dealt with the factors of dual-use as well as providing general information about the strategies and capacities of each firm. However, by just contacting the firm on a general e-mail address would most likely yield little response. Thus I followed some of the recommendations presented by several scholars (Bradshaw & Stratford, 2010, p. 75) to ‘snowball-sample’ the respondents through key informants. This was initiated by meeting with executives from both The Norwegian Defence and Security Industries Association and

[19] See descriptive statistics table 4.1 and 4.2 in Appendix 4.

The Norwegian Defence Research Establishment. Through these meetings I received valuable information on the firms of interest, as well as names on individuals whom might likely agree to an interview, and that could further refer me to others.

As soon as the first potential interviewees were decided, I sent out several 'letter[s] of introduction' (Yin, 2009, p. 84) clearly presenting the objectives of the thesis, their specific contribution, duration of the interview as well as the possibility of anonymity (Dunn, 2010, p. 113; Marshall & Rossman, 2011, p. 101). I received feedback from all of the potential informants fairly quickly, and nearly all were positive with the exception of one firm that did not wish to participate. In the end the number of respondents totalled six individuals from five defence firms (five face-to-face interviews and one telephone interview).

In qualitative research, the 'saturation point' is often the answer to how many respondents one should interview (Kvale, 2007, pp. 43–45). With not that many firms receiving civilian citations as well as covering the cited technological fields, I believe that the information gathered from the interviews of the five firms gave me a sufficient amount of information. I argue this because adding firms that have patented technologies of no civilian value would yield little useful information about the extent of dual-use, as well as on the different factors for such spillovers.

In table 4.2 all the respondents that were sampled from the results of the patent analysis, and that agreed to be interviewed are represented. The patenting firm is denoted as well as the informant's position and the location where the interviews took place. All interviews were conducted between January and February 2013. I choose to anonymise all the respondents' names as some requested anonymity. In addition, their specific name is also irrelevant as it is the firms I have asked about. The table also shows the main technological fields in which they have patented within. The fields marked in italic are also those that received most civilian citations, as remarked above.

**Respondents**

| Firm | Main patented technologies | Location | Position |
|---|---|---|---|
| Kongsberg Defence and Aerospace | *Engine, pumps and turbines*<br>*Measurement*<br>Mechanical elements | Kongsberg | Vice President, Marketing and Business Development |
| Nammo AS | Civil engineering<br>Mechanical elements<br>Weapons and munitions<br>*Machine tools*<br>*Materials and metallurgy* | Oslo | Special Advisor |
| Nera (Now Ceragon Networks) | *Telecommunications*<br>*Digital communication* | Bergen | The current Sales Director<br>*and*<br>The former Sales Director |
| Sensonor AS | *Measurement*<br>Semiconductors | (By phone) | Vice President, Marketing and Strategic Sales |
| Nacre AS (Now Honeywell Int) | *Audio-visual technology* | Oslo | Research Director at SINTEF ICT |

**Table 4.2** List of respondents. Sampled according to the most civilian cited defence firms and technological fields.

In addition to represent the most civilian cited defence firms as well as technological fields, these firms represent also the variety of heterogeneous firms in the Norwegian defence industry. Both Nammo AS and Kongsberg Defence and Aerospace are reckoned as among the largest and most influential enterprises in the industry, and are considered as 'system integrators' (Blom et al., 2012, pp. 5–9; Castellacci & Fevolden, 2012, p. 21).

The three other firms are considered as 'specialised suppliers' (Blom et al., 2012). Sensonor is a small high-technology firm located near Horten, which produces innovative electronic solutions for both other defence firms as well as civilian industries. Nacre and Nera are two companies that in 2007 and 2011 were bought up and merged with new firms (Dragland, 2007; Finstad, 2012). The respondents from Nera have worked there for several years, and have continued to do so also in the new corporation, Ceragon Networks (for simplicity, I will continue to use Nera as the firm name). Nacre was sold to the French firm Bacou-Dalloz in 2007, which later merged with the large US defence contractor Honeywell. Nacre achieved most of its success by developing advanced earplug technology for the military (Dragland, 2007). Thus Nacre held a very specialised knowledge base within the domain of audio-technology. The way the respondents from each of these two firms were selected was through thorough reviews of press releases as well as newspaper articles to find key informants with long service in the prior firms. The respondent from Nacre is currently working at SINTEF[20] (Dragland, 2007). In fact, Nacre was a spinoff firm from SINTEF ICT, and the respondent was one of two main individuals that developed their core technologies and followed the firm until it was sold (Dragland, 2007). Moreover, the reason why there are two interviewees from Nera is that the first respondent invited one of his former colleagues who had even longer service in the firm and with substantial knowledge of the company's military relations.

### 4.3.2 Data collection

The specific tool chosen to collect the qualitative data was with semi-structured interviews. This specific type of interview procedure enabled each interview to evolve around a theoretical assumption as well as providing sufficient flexibility to the interview it self (Dunn, 2010).

Prior to each interview I had constructed an interview guide[21] that thematically addressed both the concept of dual-use and the factors for defence–civilian spillover. The structure of the questions were organised in a 'pyramid structure' (Dunn, 2010, p. 108), whereas the questions in the start were easy to answer, thus introducing the topic, continuing on to address specific factors. Even though it was considered important to get each respondent's opinion on the former, the interviews were still initiated by giving the respondent the opportunity to freely talk about their firm, its innovativeness and products. This was done with the intention of promoting 'rapport' with the respondent (Punch, 2005, p. 174; Dunn, 2010, p. 112), but also to have examples to which both the respondent and I could relate when questions came about the factors. This proved particularly beneficial in retrospect by that they gave information that I would probably not have gained otherwise.

During each interview I chose not to primarily take notes, but relied on a tape recorder. Because, by taking extensive notes during an interview could be distracting and interrupting for the free flow of conversation (Kvale, 2007). However, not all the interviews were carried out face-to-face and were recorded. One was conducted by telephone. This proved particularly difficult when it came to transcription, as it was challenging to record the voice simultaneously. As an interview face-to-face is excellent in assessing whether questions are misplaced or if there are any incongruence (Dunn, 2010), interviews by phone does not that

[20] SINTEF is the largest independent research organisation in Scandinavia.
[21] The interview guide is presented in appendix 5.

easily enable such checks of verification. I also experienced that this particular interview yielded less useful information compared with others conducted face-to-face.

### 4.3.3 The process of analysis

The interviews of the five defence firms accumulated a substantial amount of information, and the processing and analyses of the interviewees' responses were vital to answer the research questions. The process of analysis involves not only selecting the relevant information for the study, it also entails reflecting on how it should be transcribed, analysed and verified.

McCracken (1988, p. 41) stated: 'The analysis of qualitative data is perhaps the most demanding and least examined aspect of the qualitative research process'. The multitude of approaches to such analysis also complicates this matter. Nevertheless, the first step of analysis that most scholars do agree on is the initial phase of transcription (Punch, 2005). Thus reporting how the transcriptions were conducted (Kvale, 2007). As soon as each interview was conducted I started transcribing, as the dialogue was reasonably present to mind. Since the interviews were conducted in Norwegian, this was also the language they were transcribed in. In order to ensure that I did not miss any vital information due to mishearing or because of any presumptions about the topic, I used a computer transcription tool[22]. This software program enabled me to slow down the pace of speech, rewind and pause. This proved valuable by that I could write down the complete interview in detail, as well as add comments where the interviewee showed pictures or demonstrated with their body language.

With all interviews conducted and transcribed the texts were analysed. The means of such analyses are manifold, as with the ways of transcription (Punch, 2005; Kvale, 2007). These particular interviews were analysed in a pragmatic manner, or what Kvale (2007, p. 115) term as 'bricolage'. This way of analysis is commonly used in interview analysis whereas the techniques are ad hoc, a free interplay of techniques, rather than a strict discourse or linguistic analysis. Kvale (2007) also particularly recommends this pragmatic approach of analysis when conducting research based on mixed methods (Kvale, 2007, pp. 116–117). To further ensure that I did not misinterpret any information or infringe the integrity of any respondents, citation checks were sent out for confirmation. Even though the citations were

[22] Google Chrome Transcribe Tool – available at: https://chrome.google.com/webstore/

re-written into English and fairly direct, none of the respondents had critical remarks.

Throughout the analysis, the focus was always on learning about each respondent's opinion of the hypotheses mentioned above. But also to seek additional information about their thoughts on dual-use technologies, company relations to civilian industries both domestic and internationally, and how policies inflict such technologies. Probably the most interesting aspects gained from the interviews and the subsequent analyses were that the industry was even more heterogeneous than expected. Because a lot of the knowledge gained through documentation processes, such as reading annual reports and firm biographies, was not always offering an accurate picture of a firm compared to the information gained from the interviews.

## 4.4 Validity and Reliability

The process of research in this thesis with both qualitative and quantitative approaches is assessed in terms of validity and reliability. The means of precisely describing and discussing the approaches taken in collecting and analysing quantitative and qualitative data, is to give the reader a thorough overview of the process as well as to demonstrate the validity and reliability of the thesis. Even if this section discuss the aspects of validity and reliability, it has as Kvale (2007, p. 123) recommends, been a part of the whole research phase.

Validity revolves around whether the instruments one have used to collect and measure data, actually measures what it is claimed to do, and how well these data represent the phenomena studied (Punch, 2005, p. 29; 97). The former is in reference to the validity of the data. However, it is also needed to assess the overall validity of the research, whether the different parts of the study fits together. In addition, the aspects of internal and external validity, which accordingly means: if the study reflects a real-life phenomenon and to what extent the study could be generalised to other settings (Punch, 2005, p. 29). Through the previous chapters describing the quantitative means conducted I argue that this approach proves validity in the study of the concept of dual-use technology, even though patent analysis is only one possible way of studying dual-use. The supplementing of data from other sources (as with the FFI datasets on the defence industry) gives also additional data to the study. However, by that I have not collected these myself and that they correspond to different time-periods could pose a potential bias. Nevertheless, by combining this approach with qualitative interviews to further discuss these inquiries could generate internal validity.

When it comes to assessing the validity of qualitative research Kvale (2007, p. 123) argues that the continually checking, questioning and theoretically interpretation of the results is means of assuring validity. In addition, by that the qualitative approach further inquires the findings of a quantitative study, and these two methods fit together, the argumentation of results becomes more rigid and the research at whole gains validity (Punch, 2005, p. 247; Winchester & Rofe, 2010, p. 21). Nevertheless, the knowledge gained from qualitative research cannot be generalised, at least not in statistical terms. This is not the purpose of such research (Kvale, 2007, p. 87). However it can offer 'transferability' (Baxter, 2010, p. 94). Thus, if anyone attempts at applying these results on other nations defence industry's these findings will not be true for those, however, some of the theoretical knowledge gained about dual-use technology might be, hence giving what is known as 'analytical generalisation' (Kvale, 2007, p. 127).

Reliability on the other hand pertains to the consistency of a study (Punch, 2005, p. 95). It is often treated in relation to the issue whether the results can be replicated by others and at other times (Kvale, 2007). As the methodological chapter so far has sought to show, the possibility of reproducing this thesis' findings are possible, at least in terms of the quantitative approach. However, assessing reliability of a qualitative study is more challenging, as one is dealing with people and their opinions. Nevertheless, I have shown both how the interviews were conducted, transcribed, and which firms that were interviewed. In addition I have also strived to re-check the answers given by the interview subjects through citation checks, but also re-listened to the sound recordings to control for discrepancies.

## 4.5 Ethical Considerations

In both quantitative and qualitative research ethical issues can arise, however, often more acute in the latter approach (Punch, 2005, p. 276). Nevertheless, in this thesis ethical discussions of both of the conducted approaches are considered.

The study of an industry that is often associated in the public media with questionable trade agreements, or that the existence of this industry is fuelled by armed conflicts could in itself pose certain ethical difficulties. Nonetheless, this thesis aims to study some of the potential benefits of this industry. Whether the technology that is developed could find wider applications in the civilian market, and perhaps even contribute to social benefits for the public good.

When it comes to the quantitative approach, precautions have been taken in order not to present the results so that any information could bring harm or liability upon the firms studied. This has been especially important with data that present in detail company survey responses and firm specific account data.

On the other hand, the qualitative approach has demanded a broader consideration of ethical implications. The respondents are all anonymised as there are no obvious reasons of presenting their names when they speak about their employee. In addition, the respondents gave their fully informed consent in advance of the interview (Dowling, 2010), as well as the possibility of citation checks. Through such measures I have attempted to fulfil the principle of beneficence, by exercising ‘no harm and maximizing the possible benefits while minimizing the possible harms’ (Ragin & Amoroso, 2011, p. 89). In addition to the more obvious ‘don’ts’ in social research, which Ragin and Amoroso (2011) describe as plagiarism, concealment or publication of fictional data, have been avoided. This section on ethical considerations is as much important as the rest of the thesis. Whereas, by presenting and discussing the variety of steps taken, I hope to give the reader a transparent perspective upon the process of research.

# 5. Quantitative Results

The quantitative results show that defence–civilian spillovers from the Norwegian defence industry to civilian sectors can be observed to a certain extent. The statistical analysis of the hypothesised explanatory factors for dual-use argue that those factors that have a significant effect on spillovers are: broad technological competencies, high efforts in innovative capabilities, and firms that are heterogeneously orientated in defence and civilian markets. These results function as to answer the research questions through a quantitative lens, on the basis of an empirical collection of military patents, citations and firm-level data.

The results from the collection of patents are presented in the next section, where the patenting activity over time and the technologies from the Norwegian defence industry are discussed. The subsequent inventive response of these military patents is the collected patent citations, and the presentation of this function as the basis for further discussions of defence–civilian spillovers. Followed by the two former sections, the civilian patent citations, the extent of this, the type of technologies, and the countries of origin will be shown. These aspects answer the first research question, of what is the extent of defence–civilian spillovers from the Norwegian defence industry to civilian sectors. The next sections attempt to answer the second research question, what factors that could explain this pattern of defence–civilian spillovers. From six logistic regressions, the results will indicate which of the hypothesised factors that matter for defence–civilian spillovers. In the final section the results are summarised.

## 5.1 Defence Patenting

The patenting activity of the Norwegian defence industry is the basis for the defence–civilian spillovers from the industry. During the last 41 years the firms in the industry have publicised many patent applications of various technologies. The patented technologies give a representative picture of the different technological competencies inherent in this industry.

Figure 5.1 shows the distribution of military patenting technologies, by year of application.

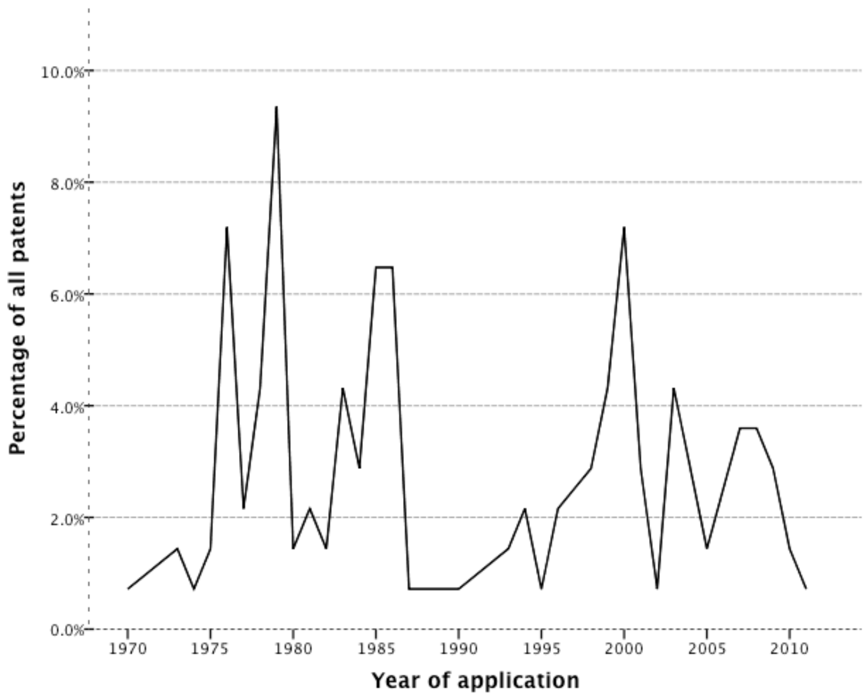



**Figure 5.1** Distribution of patent applications from the defence industrial base (N=139).

The figure above shows that the patenting activity of military technologies from the industry is quite spread, with no clear tendency. Moreover, the mean annual rate of patenting is 4 patents per year (when calculated from annual frequency). Considering the general patenting activity there are no other industrial studies in which to compare. However, as it was commented in the chapter above (chapter 4), industry's propensity to patent varies greatly (Levin et al., 1987; Granstrand, 2005). Thus, with an industry producing advanced technologies, especially at the level of components and subsystems (Bitzinger, 2003; Blom et al., 2012), this mean annual rate of patenting could be considered quite low in general terms, at least if one compares it with the knowledge on patenting activities in industries such as pharmaceutics (Granstrand, 2005, pp. 280-281).

Nevertheless, these patents represent inventions with military applications, a field of innovation where other researchers have noted a strategic tendency to secrecy (Bellais & Guichard, 2006). If I were to consider all patented technologies from the Norwegian defence industry, disregarding a validation of military applications. One would see far more patents, and even more citations. This was also noted in the section on collection of data, where I found in total 320 patents of both civilian and military application. Nonetheless, as the next section will show, these 139 military patents receive multiple citations, which might be due to the vast variety of technological fields in which these patents are denoted to.

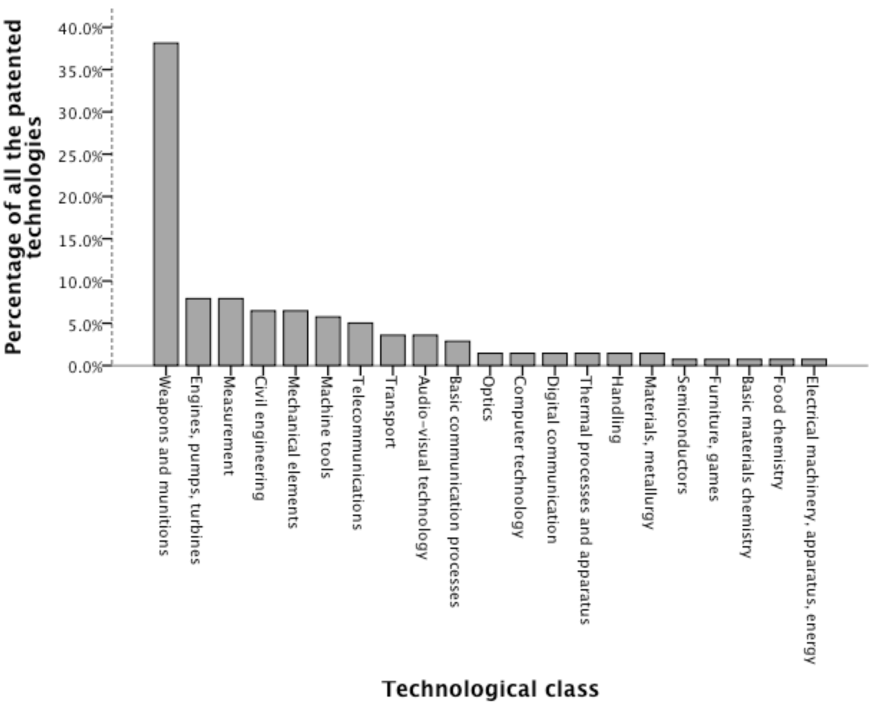



**Figure 5.2** Distribution of patented technologies, by technological class (N=139).

Figure 5.2 above shows the distribution of all patented military technologies. These are categorised into 21 different technological fields, in accordance to the technological concordance table from WIPO (2011)[23]. Not surprising, the main patented technology from the defence industry are weapons and munitions, which exceeds the second most patenting class (engine, pumps, and turbines) with over 30%. The number of firms patenting within this field are few, consisting of 6 firms, which is similar to the argumentation in Fevolden and colleagues (2011, p. 21), where only a small share of firms are devoted to such production.

Several other technological fields retain the remaining patents. Here, most of the fields could be viewed within two broad categories: electronics- and communication technologies, and material- and mechanical technologies. These technological groups of patenting are similar to two of those reported in Fevolden et al. (2009, p. 56), as areas of competence that the industry holds. Moreover, this supports what Griliches (1990) argued – that patents are not only a production output, but also a good proxy for the knowledge base.

[23] See appendix 3, table 3.1 for this classification sheet.

## 5.2 Citations

The citations are important because they show the inventive response to former military patents. Even if the civilian citations are the proxy for defence–civilian spillovers, military and self-citations are important to give an overall view the citations. These citations both hold a substantial amount of the inventive response, but do also represent the value of 0 as non defence–civilian spillovers in the regressions.  Nonetheless, with these citations it is possible to trace the 'paper trail' of knowledge (Jaffe et al., 1993, p. 578). Such paper trails enable quantitative assessments of the extent of spillovers of defence-originated patents.

In figure 5.3, the green line represents military citations, the blue line civilian citations, and the dotted line self-citations. The first citation that an original defence patent received was a self-citation in 1974, and the most recent was registered in late 2012. Thus, the citations are distributed over a period of 38 consecutive years.

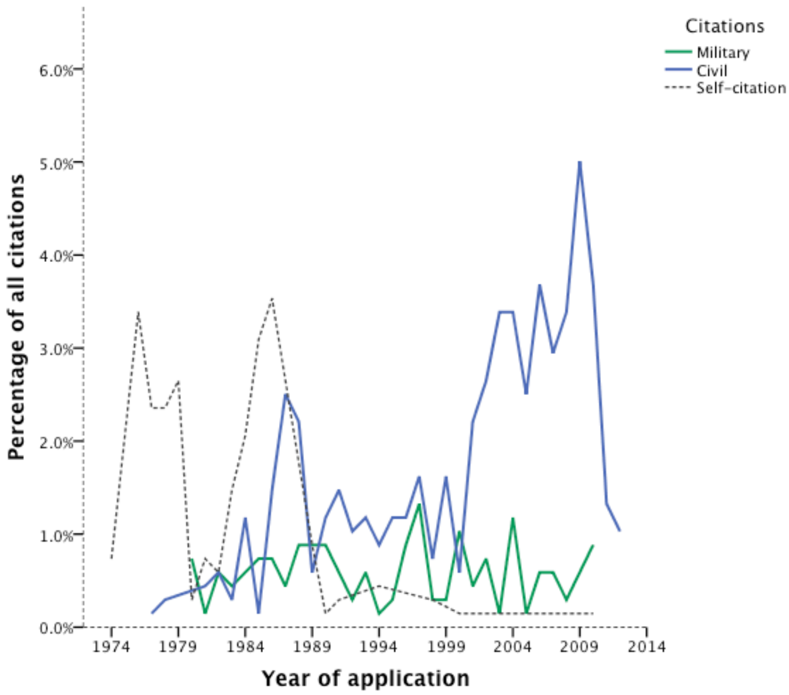



**Figure 5.3** Distribution of citations by year of application. Military citations marked in a green line (n=111), whereas civil citations are marked in a blue line (n=392), and self-citations in a dotted line (n=176).

The figure shows that the different types of citations are distributed quite differently over time. Self-citations, which are patent applications by the same firm or the inventor (Jaffe & Trajtenberg, 1999), peaks in two periods from 1974 to 1990, and declines to nearly zero from 2000. These citations do not represent defence–civilian spillovers, and would rather be an indication of intra-firm spillovers, perhaps not even spillover at all.

The military citations remain fairly stable over time, and represent only a little amount of the citations compared to the civilian ones. Which in turn is consistent with the assumption of the relative propensity to patent military technology (Bellais and Guichard, 2006). The military citations are an indication of spillovers, however the specific type of spillover is defence-defence spillovers, and could not be considered as dual-use technologies.

The civilian citations of the defence-originated patents represent the indication of civilian usage of defence technologies, hence defence–civilian spillovers of dual-use technologies. These citations vary over time, and peaks multiple times. Especially the two major inclines of civilian citation from 1985 to 1990, and from 2000 until 2010, could be viewed as corresponding with the amount of patenting from the Norwegian defence industry (see figure 5.1). Nonetheless, it is these citations that are important for showing the extent of spillovers of dual-use technologies from the Norwegian defence industry.

## 5.3 Extent of Dual-Use Technology

The civilian citations presented above and in the figure below contribute to answer the first research question, to what extent defence–civilian spillovers can be observed. Moreover, these citations do not only represent evidence of the extent of dual-use technology, but also what type of technologies these spillovers are, and what countries they diffuse to.

There is only one earlier article addressing dual-use technology through the means of analysing patents and subsequent citations. Acosta and his colleagues (2011) were apparently the first to combine economic studies of technological spillovers with the concept of dual-use technology. In their publication they commented (p. 338) that they employed the measure of forward patent citations as a proxy for knowledge spillover from the military to civilian sectors, uncovering one way of identifying dual-use technology. Even if patents and subsequent citations could be considered as only inventions that might potentially result in innovations. The subsequent civilian citations of military technology have been argued to be a clear indication of new applications of technology, hence in accordance to the definition of dual-use.

In the figure below where military and self-citations have been removed, one important finding is clear. The steep incline of civilian citations from the year of 2000 until 2010 indicates that defence–civilian spillovers of dual-use applications have increased over the last decade. This is contrary to what other scholars (Avadikyan et al., 2005; Stowsky, 2004; Molas-Gallart & Sinclair, 1999) have argued, that civilian developments have surpassed defence developments, and decreased its relevance. The steep incline suggest otherwise, and that this is not true for some technologies developed by the Norwegian defence industry.

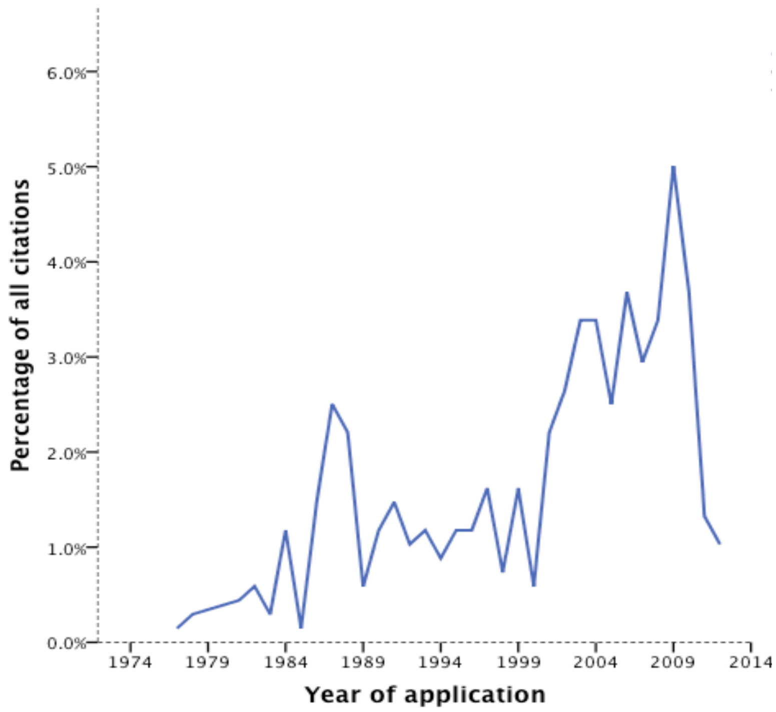



**Figure 5.4** Distribution of civilian citations (n= 392) by year of application.

The sudden decline in citations after the year of 2010 is mainly due to that many citations are yet to come, since the time span of citations ends in 2012. This is an aspect that was commented in the methodological chapter, and might pose as a possible truncation bias of the data (Trajtenberg, 1990).

The next figure 5.5 shows which technological fields the civilian citations are distributed in when removing self-citations and military citations. The figure clearly presents multiple technological fields where new applications of technology are used in. There exist a great variety of civilian dual-use applications of defence technologies. Nonetheless, many of the technological fields that military applications were patented in seem to also be well cited in equal fields (see figure 5.2). This supports to some degree the findings by Verspagen and

Loo (1999), that remarked that technologies are often cited in same or close lying areas of usage.

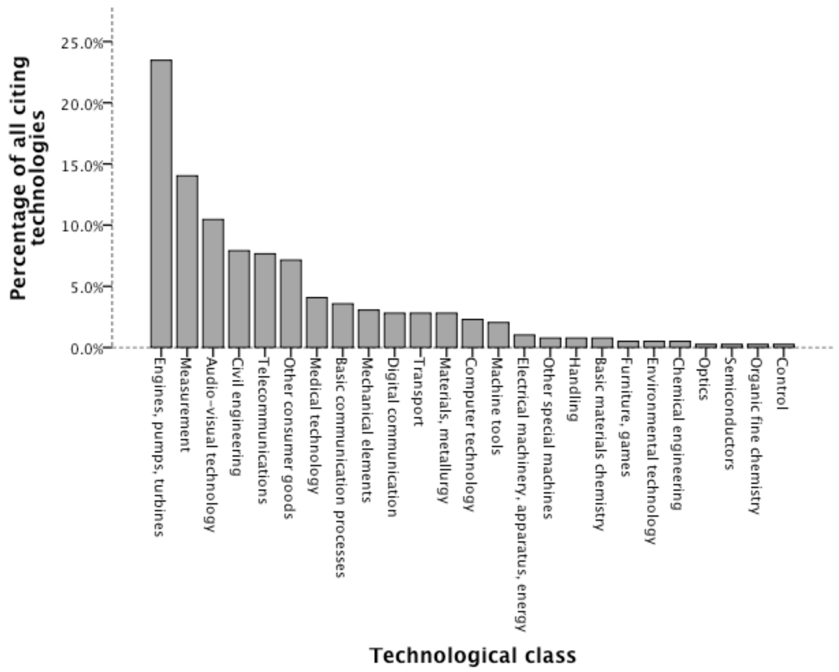



**Figure 5.5** Distribution of civilian citing technologies (n=392). Self-citations (n=172) and military citations (n=111) have been removed.

However, many of the citations are not within close lying technological fields, but are within new technological areas, such as medical and environmental technology. For example, some of the military patents on audio-visual technology received several civilian citations from firms producing products with similar technologies. However, some of the citations were also from firms producing medical technologies. The advanced technological competencies inherent in these patent publications have been used in new civilian applications such as hearing-aid products for people with severe hearing deficiencies. But it has also been applied to improve patient communications in magnetic resonance imaging machines (MRI).

Another example of spillover is a patent published by the Norwegian defence firm Nammo, on the process of producing an aluminium alloy with extreme functional requirements, which was used in the military rocket launcher M72-LAW (Light Anti-Tank Weapon). This particular patent received many civilian citations, especially from firms in the car manufacturing industry. This patent is also known to have been one of the main success factors for the industrial development at Raufoss (Eger, 2009). In fact this aluminium alloy actually set the developing stage of today's car bumper alloys (Eger, 2009, p. 273).

In addition to the various technological fields that the civilian citations are cited in, the nationalities of those who cite are also quite spread. When considering civilian citations the international distribution is evident, especially for the US, some European countries, as well as Japan.

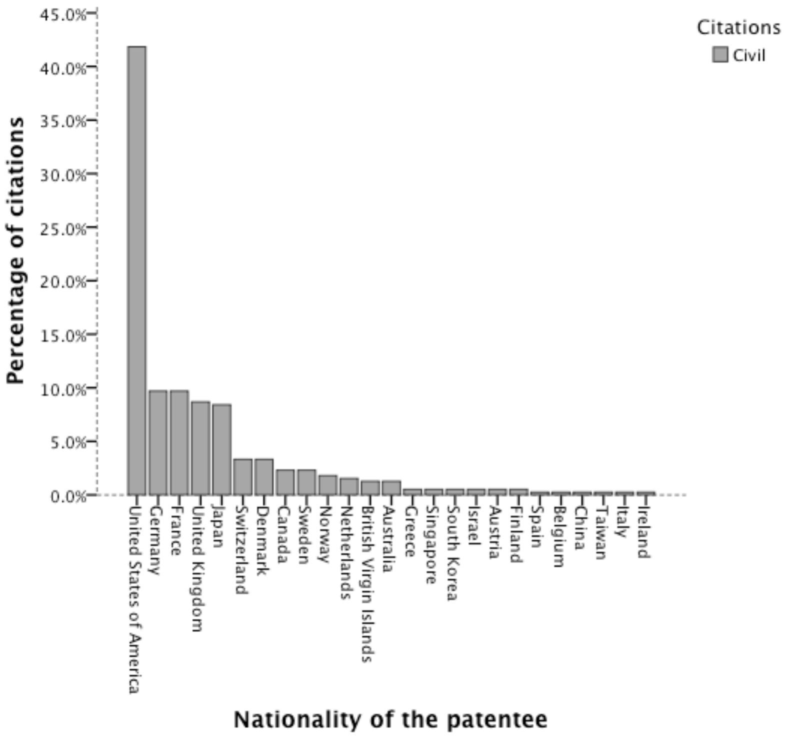



**Figure 5.6** Distribution of civilian citations by nationality (n=392). Self-citations (n=172) and military citations (n=111) have been removed.

The descriptive data show that patented technologies from the Norwegian defence industry generates new civilian technologies in multiple countries of origin. Some countries stand out compared to others, especially the US with 41% of the citations and some European countries (Germany 9.6%, France 9%, UK 8.5%). The country distribution above does also seem to support Acosta et al. (2011, p. 347) findings, by that USA is the country that makes the greatest use of military technologies for civilian purposes, followed by Germany. These descriptive results are quite similar to what was found in the former study: USA with 50.6%, followed by Germany with 16.8% of the citations (Acosta et al., 2011, p. 347).

All of the former countries have close collaborative traits with Norway as export partners of military technologies through their NATO memberships. For that reason, domestic civilian industries with close ties to national defence industries might have better opportunities in encountering new technological developments, which might be applied in civilian applications.

Nonetheless, one interesting finding is that the defence–civilian spillovers have a substantial international character compared to the amount of domestic citations (1.79% of the citations). This means that spillovers from the Norwegian defence industry are affecting industries abroad more than domestic civilian industries.

The relative closeness to these countries might also matter. Scholars like Jaffe and colleagues (1993) argue that from studying citation spillovers of technology, that geographical closeness matters in the use of technological knowledge. Thompson and Fox-Kean (2005) later corroborated these findings, by that they also found evidence of international localisation effects, however, they did not find any sustainable evidence of intra-national effects. Even so, this thesis does not aim to provide evidence of geographical spillovers as the authors above. However, the geographical closeness is probably not the only explanatory factor for the substantial international use of Norwegian military technology. Since the figure above also shows that Japan, as one of the Asian countries, use military technology for civilian purposes (with 8% of the citations). In Acosta et al. (2011) study, Japanese companies was also discovered to have great propensities in using military technologies for civil purposes.

Collectively, the figures above show that the civilian citations indicate a certain 'extent' of civilian usage of dual-use technologies. However, to what extent is constrained by both aspects of time in patent data and the limited studies in which to compare with. As noted in both the methodology[24] and in the descriptive figures above, military patents were cited by 392 civilian patents (111 military and 176 self-citations). The civilian citations were distributed over 25 countries and 25 technological fields, indicating a clear extent of civilian use of defence originated technologies, both internationally and to several technological fields, thus several industrial knowledge bases. Still, these original defence patents continue to generate dual-use technologies in civilian industries by that many of these will continue to receive citations in an unforeseeable future.

Moreover, for a civil patent citation the mean lag is 11.6 years, and the longest time lag registered is 38 years. Thus, the question 'to what extent' the civilian industries use dual-use technologies from the Norwegian defence industry can yield only a time-limited answer.

[24] See figure 4.2 in chapter 3

However, to even give a temporary answer other than the specific amount given above is also rather challenging. Whether the extent of dual-use technology is larger or smaller than other industries of patenting is difficult to ascertain, as there are very few other studies of defence industries that employ the same approach. Acosta and his colleagues (2011) for example collected only patents on weapons and munitions from a variety of national patent databases in order to gather enough data. Not from a specific national industry, nor military technologies in general. Nonetheless, the extent of civilian usage of defence originated dual-use technology is clearly shown in the descriptive section above.

## 5.4 Explanatory Factors of Dual-Use Technology

The four explanatory factors, external cooperation, technological breadth, innovative capabilities, and civilian orientation, were all assumed to affect defence–civilian spillover. To answer the second research question of what factors explain the pattern of spillover, six logistic regressions test the aggregated indicators for these factors. The results contribute to give a stylised picture of the ideal dual-use producing defence firm, in addition to support earlier studies of dual-use technology.

Retracing figure 3.1 from the theoretical chapter showing the factors for dual-use and the accompanying hypotheses, the following figure 5.7 shows a regression matrix. The figure represents the hypotheses and the explanatory variables. Together with each variable box a beta-value is presented to indicate whether the expected outcome is positive or negative.

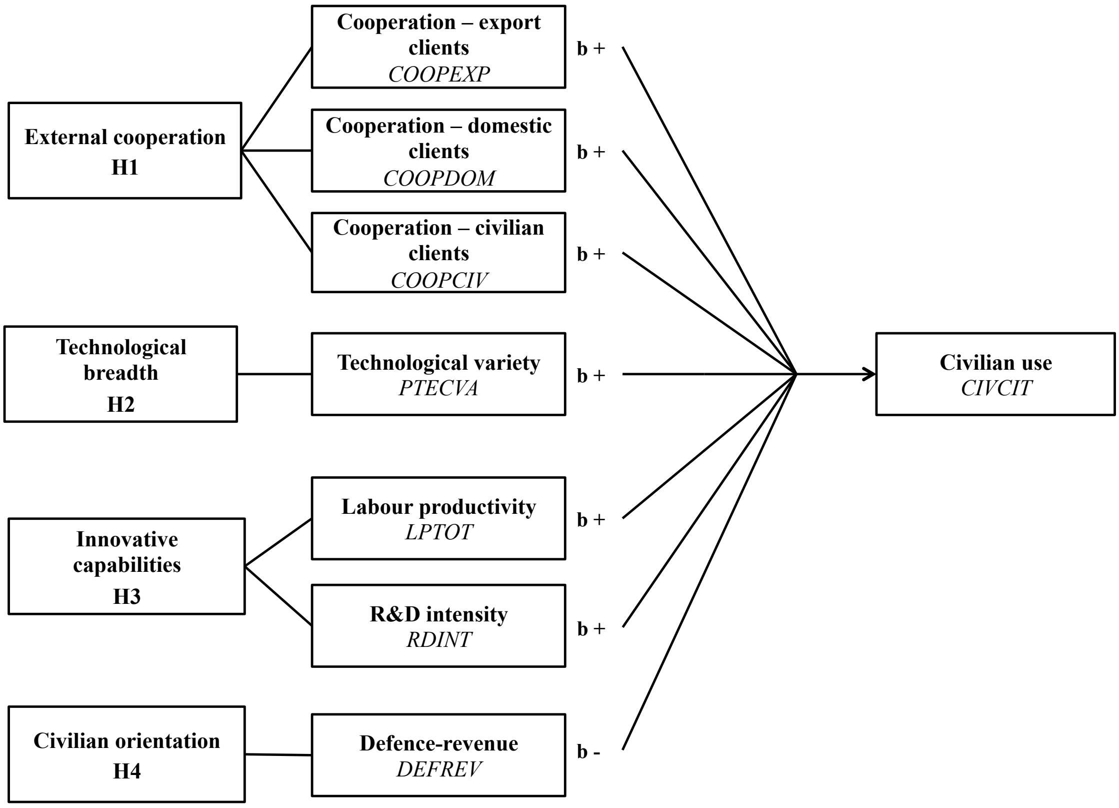



**Figure 5.7** Regression matrix.

In the forthcoming regressions two additional variables are included. One, controls for citation lag and the possibility of severe truncation in the dataset. That is a potential bias of missing significant amounts of citations, since these will continue to come in even after the data collection has ended. The other, controls for international citations, as there are very few domestic citations in the dataset. Both of these control variables are also included in all the regressions as they contribute in strengthening the overall fit of the models.

Table 5.1 presents the descriptive statistics of the variables included in the regressions. Table 5.2 shows the results from the logistic regressions: coefficient, significance level and the odds ratio for each variable. In the two bottom rows in each of the six models, the model fit (Cox & Snell R Square and Nagelkerke R Square), and the number of observations are presented.

As noted in the methodology chapter, I have chosen to employ six regressions in order to avoid the methodological challenges of possible collinearity between the variables. The number of regressions were needed due to that the three variables testing H1 measured about the same. Moreover, the two variables on H3 also measured similar values, but needed to be included in the regressions with the former variables.

**Descriptive statistics**

| Variable | Observations | Mean | s.d | Min | Max |
|---|---|---|---|---|---|
| *CIVCIT* | 679 | .58 | .49 | 0 | 1 |
| *PTECVA* | 679 | 3.28 | 1.93 | 1 | 10 |
| *CLAG* | 679 | 9.08 | 8.49 | 0 | 38 |
| *DINT* | 679 | .73 | .44 | 0 | 1 |
| *DEFREV* | 672 | 86.51 | 28.77 | .00 | 99 |
| *LPTOT* | 673 | 3294.92 | 1125.77 | 1298.7 | 4732.1 |
| *RDINT* | 673 | 7.6 | 2.81 | .00 | 10.1 |
| *COOPEXP* | 655 | 3.5 | .5 | 1 | 4 |
| *COOPDOM* | 655 | 3.6 | .86 | 1 | 4 |
| *COOPCIV* | 655 | 2.3 | 1.47 | 1 | 4 |

**Table 5.1** Descriptive statistics.

**Table 5.2** Results of logistic regressions. Dependent variable *CIVCIT*

| | **Model 1** | | **Model 2** | | **Model 3** | | **Model 4** | | **Model 5** | | **Model 6** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B (sig) | Odds Ratio | B (sig) | Odds Ratio | B (sig) | Odds Ratio | B (sig) | Odds Ratio | B (sig) | Odds Ratio | B (sig) | Odds Ratio |
| *PTECVA* | .33 (<.001) | 1.39 | .31 (<.001) | 1.35 | .35 (<.001) | 1.42 | .32 (<.001) | 1.38 | .35 (<.001) | 1.42 | .30 (<.001) | 1.35 |
| *CLAG* | .03 (.089) | 1.03 | .02 (.136) | 1.02 | .02 (.121) | 1.02 | .02 (.097) | 1.03 | .02 (.115) | 1.02 | .02 (.115) | 1.02 |
| *DINT* | 4.43 (<.001) | 84.08 | 4.21 (<.001) | 67.41 | 4.56 (<.001) | 95.40 | 4.40 (<.001) | 81.77 | 4.55 (<.001) | 94.98 | 4.26 (<.001) | 70.67 |
| *DEFREV* | -.02 (<.001) | .98 | -.17 (<.001) | .85 | .01 (.217) | 1.01 | -.04 (.011) | .96 | -.02 (.001) | .98 | -.19 (<.001) | .83 |
| *LPTOT* | .02 (<.001) | 1.02 | | | .01 (<.001) | 1.01 | | | .01 (<.001) | 1.01 | | |
| *RDINT* | | | 1.41 (<.001) | 4.08 | | | .70 (<.001) | 2.01 | | | 1.85 (<.001) | 6.36 |
| *COOPEXP* | -3.55 (<.001) | .03 | -1.23 (.011) | .30 | | | | | | | | |
| *COOPDOM* | | | | | -1.80 (<.001) | .17 | -2.05 (<.001) | .13 | | | | |
| *COOPCIV* | | | | | | | | | -.66 (<.001) | .52 | -.74 (.003) | .48 |
| Model fit: Cox & Snell R Square / Nagelkerke R Square | .51 / .68 | | .49 / .66 | | .50 / .67 | | .51 / .68 | | .50 / .67 | | .50 / .67 | |
| Observations (n) | 654 | | 654 | | 654 | | 654 | | 654 | | 654 | |

### 5.4.1 External cooperation

*Hypothesis 1: Increased cooperation with external firms positively affects defence–civilian spillovers.*

In table 5.2 this hypothesis is tested with three explanatory variables, the valued appreciation of cooperation with export-, domestic-, and civilian clients. Each explanatory variable have been tested twice together with two explanatory variables examining hypothesis 3.

In models 1 and 2, cooperation with export clients is reported as negative and significant in both models (below 1%-level in model 1 and below 5%-level in model 2), decreasing the probability of civilian use by accordingly 97% and 70%, with one units increase[25]. The expected outcome was positive, contrary to the results. However, these results might be explained by that the more a defence firm values cooperation with export clients, that are often military, then the more specialised military products they deliver. Thus, the shared benefits of cooperation with such client's might be beneficial in developing military technologies, but the civilian applicability is reduced. Moreover, the cooperation with export clients might also be mostly in terms of offset agreements, whereas Norwegian defence firms cooperate with international military clients in developing and delivering nearly pre-defined components intended for military use.

In model 3 and 4, cooperation with domestic clients, which are non-specified whether it is civilian or military, is reported as negative and significant below 1%-level in both regressions. The odds ratio's report that the probability of subsequent civilian use decreases by 83% in model 3 and 87% in model 4, with one unit increase. As with the explanatory variable above, the expected outcome was to be positive. The results therefore indicate that increased valued importance of cooperating with domestic clients decrease the probability of civilian usage of dual-use technologies. However, in retrospect this could be explained by that many of the defence firm's in Norway considers large part of their markets to be abroad (Fevolden et al., 2008; Blom, Castellacci & Fevolden, 2011). Thus the domestic 'clients' whom they cooperate with in developing new products might be mainly their main domestic client: the Norwegian Armed Forces. It might also be that those domestic civilian clients they do cooperate with are actually quite few. Unfortunately, this is impossible to verify from the firm-level data collected.

[25] One unit's increase in all these three explanatory variables is one level on the response scale of the categorical variable.

In model 5 and 6 the final explanatory variable testing hypothesis 1 measures the valued importance of cooperation with civilian clients. The results are also contrary to the assumptions, and are reported as negative and significant below 1%-level in both regressions. The odds ratio does not indicate as strong decreasing probability of civilian citations with one unit's increase as the others above, nonetheless, reported values are accordingly: 48% in model 5 and 52% in model 6. The mean valued importance of this categorical indicator is 2.3 (table 5.1), which translates to *some importance*, indicating that defence firms do not value cooperation with civilian firms that much. Moreover, it would seem that the little cooperation with civilian firms does not generate any exchange of knowledge that later positively affects spillover.

### 5.4.2 Technological breadth

*Hypothesis 2: Increased technological breadth positively affects defence–civilian spillovers.*

From this hypothesis it was assumed that increased technological breadth inherent in a product or process technology would generate more defence–civilian spillovers of dual-use technologies. The results in all regressions confirm this hypothesis. All coefficients are positive and significant below 1%-level. Thus, the increase of one unit (measured here as a IPC reference, which indicates a technological field of use), affects the probability of a subsequent civilian citation between 35- and 42-percent. This translates to, that the more technologies a defence firm incorporates in the development of a new technology, the more relevant it is to civilian firms. Thus, increasing the potential of defence–civilian spillovers of dual-use technologies.

### 5.4.3 Innovative capabilities

*Hypothesis 3: Increased innovative capabilities positively affect defence–civilian spillovers.*

This hypothesis assumed that different innovative capabilities of a defence company would affect civilian usage of dual-use technologies from the defence sector. From the firm-level data collected, two types of indicators were discovered (commented in chapter 4). These are R&D intensity and labour productivity. In model 1, 3 and 5 labour productivity is tested, and is reported as positive and significant below 1%-level in all regressions – confirming the hypothesis.

The other explanatory variable assumed to support this hypothesis is the measured R&D intensity of a defence firm. Model 2, 4, and 6 confirm the hypothesis, where all results are reported as positive and significant below 1%. R&D intensity is a strong contributor to defence–civilian spillovers, by that the probability of a civilian citation increases by 308% in model 2, 101% in model 4, and by as much as 536% in model 6, with one units increase of 1%.

The arguments presented under this hypothesis in the theoretical chapter, concerned that the large amount of publicly financed R&D in the defence sector might 'crowd out' private R&D, which subsequently could diminish potential dual-use due to little civilian relevance (Mowery, 2010). This argument does not seem to hold here. However, in defence of the 'crowding out' argument, the regressions have not separately tested public versus private R&D.

### 5.4.4 Civilian orientation

*Hypothesis 4: Increased civilian orientation positively affects defence–civilian spillovers.*

With the explanatory variable measuring defence-related revenue, which is an indicator of defence-orientation, it is assumed that increasing defence-related revenues decreases a firm's civilian orientation. Thus a negative result counterfactually indicates that defence firms with less defence-revenues have the potential of producing more defence–civilian spillovers. The results are confirming, and are negative and significant below 1- and 5-percent level. The probability of a subsequent civilian citation, by 1% increased defence-revenue, decreases from 17- to 2-percent. The hypothesis is confirmed in all regressions except one (model 3), and indicates that civilian orientation affects defence–civilian spillovers, and that increased defence orientation consequently diminishes spillovers.

### 5.4.5 Controls

The dummy variable on international citations is used as a control variable in all models as most of the citations are international. The variable has been included as it improves the model fit substantially. The results are fairly stable in all regressions, and indicate that if the nationality of a patentee is international it affects the likelihood of a civil citation positively and significantly.

The continuous variable measuring the lag of years between the citing and the cited patent have been included in all models to control if time has any effect on civil citations. Thus if it were to be significant in all regressions the dataset might have had a problem with truncation in the data. The results indicate that the possibility of truncation bias is actually inconclusive, where in model 1 and 4 the results are positive and significant below 10%-level. These indicate that the increase of one year affects the likelihood of a civil citation by 3%. However the probability of a subsequent citation is fairly low, and indicates that only a few citations are missed. Moreover, the other regressions in model 2, 3, 5, and 6 are positive but non-significant. Since not all results indicate that increased time will affect the number of forthcoming citations significantly, and that the probability is low in those that are significant, the risk of truncation is considered acceptable. Figure 5.7 below illustrates the citation lags of both military and civilian citations, and as the figure shows the mean lags are quite long.

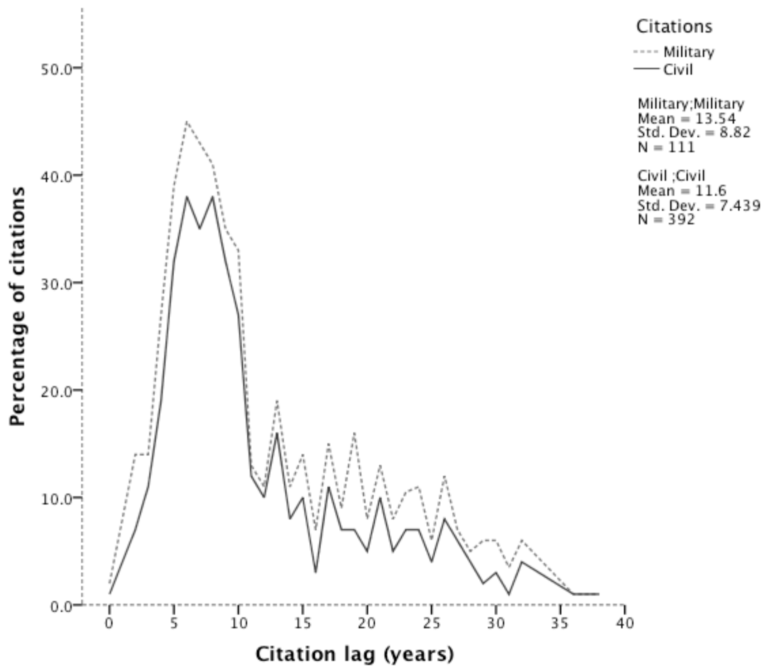



**Figure 5.8** Citation lag. Lag of years between the citing and the cited patent. Self-citations removed (n=176).

## 5.5 Summarising the Results

The descriptive sections above on both defence patenting and citations showed that patenting, as an empirical approach to investigate the extent of dual-use technology from the Norwegian defence industrial base, is adequate. The results indicate that evidence of defence–civilian spillovers of dual-use technologies from the industry can be observed. Moreover, to what extent these spillovers can be observed is limited by both the aspects of time in patent data and the lack of comparable studies.

The descriptive part has further made two important findings: The first is that defence–civilian spillovers have increased the latest decade, a finding which is contrary to what some other scholars have held (Avadikyan et al., 2005; Stowsky, 2004; Molas-Gallart & Sinclair, 1999). The second important finding is that the military patents receive a substantial amount of international citations compared to domestic citations. This finding indicates that most of the defence–civilian spillovers are utilised by industries abroad, and that the domestic spillover effect is only modest. This could be an important policy implication by that the governmental support to Norwegian defence firms only generates limited national effect.

Figure 5.3 presents a summary of the results of the logistic regressions, indicating the effect of the hypothesised drivers of dual-use technology.

**Summary of results**

| Hypothesis | Formulation | Results |
|---|---|---|
| H1 | Increased cooperation with external firms positively affects defence–civilian spillovers.<br>Explanatory variables: *COOPEXP, COOPDOM, COOPCIV.* | Not supported |
| H2 | Increased technological breadth positively affects defence–civilian spillovers.<br>Explanatory variable: *PTECVA.* | Confirmed |
| H3 | Increased innovative capabilities positively affect defence–civilian spillovers.<br>Explanatory variables: *LPTOT* and *RDINT.* | Confirmed |
| H4 | Increased civilian orientation positively affects defence–civilian spillovers.<br>Explanatory variable: *DEFREV.* | Confirmed, except model 3 |

**Table 5.3** Summary of logistic regressions results

The results in table 5.3 give a stylised picture of a defence firm that will produce defence–civilian spillovers. Thus, if a firm increase the technological breadth of a product, its labour productivity, R&D intensity, and take a heterogeneous position by producing goods for both defence and civilian customers, then the more dual-use technologies they will produce.

The preceding results have been viewed through a quantitative lens. The next chapter seeks to deepen the perspective through interviews. From a qualitative perspective this can facilitate in-depth discussion of the extent of dual-use technology, as well as the hypotheses. Furthermore, the approach will give new information from the interviewees of various firms, thereby providing a clearer picture of the factors affecting dual-use technology.

# 6. Qualitative Results and Analysis

The results from the qualitative analysis show that the there are several examples of defence–civilian spillovers from the five most dual-use producing defence firms in the Norwegian defence industry. The examples vary between the firms in terms of numbers and technological importance. Some of the firms do also seem to have taken an active role in promoting defence–civilian spillovers. However to some others, the spillovers are considered as a more indirect effect of their developments.

The views on the theoretically proposed explanatory factors for spillovers vary, and the results show that the way these factors affect spillovers are complex. This indicates that the defence firms are not only highly heterogeneous in terms of firm structures, but also in the way they consider technologies to spill over. Some of the interviewed representatives also said that there are additional aspects that could explain defence–civilian spillovers.

Nevertheless, the qualitative approach provides valuable knowledge to answer the research questions: the extent of defence–civilian spillovers and the explanatory factors. The results does also support and deepen the understanding of the statistical results.

The first section below introduces the five defence firms where the key respondents are employed. The following sections address the first research question, and present the qualitative evidence of dual-use technology from five different defence firms[26]. The next sections examine the information gathered from the interviewees on the factors assumed to affect spillovers of dual-use technology. In the final section the qualitative results are summarised.

## 6.1 Defence Firms

The defence firms that the key respondents were selected from were all sampled from the patent analysis. The five firms: Nammo, Kongsberg Defence and Aerospace, Sensonor, Nacre, and Nera, were all firms that produced the most defence–civilian spillovers of the patenting firms in the industry[27]. These companies do also represent the most cited defence technologies.

Even though this group of firms produce defence–civilian spillovers, the firms are still very diverse, in terms of size and range of products. Two of the largest defence firms,

[26] For list of interviewees, see table 4.2 in chapter 4.
[27] Initially there were six defence firms that were sampled, but one firm declined to take part in any interviews.

Kongsberg Defence and Aerospace and Nammo, produce multiple products and hold a wide variety of competencies (Castellacci & Fevolden, 2012). These firms deliver complete weapon systems or platforms, but also advanced components. The three smaller firms, Nera, Sensonor, and Nacre, produce specialised components or basic stand-alone military equipment (Blom et al., 2012).

Kongsberg Defence and Aerospace (from now on KDA) have a quite long track record as a defence firm in Norway, and are today an international competitor in a number of different areas (Castellacci & Fevolden, 2012, p. 37). KDA was established as an arms producer in 1814 at Kongsberg[28] (Kongsberg, 2013). The enterprise has also changed names and business structures over time. Currently, KDA is the military branch of the enterprise Kongsberg Group that was established in 1987 (Kongsberg, 2013). This group consists of several firms providing both technologies to the military and civilian sectors, however, KDA are mainly devoted to military technologies. Their areas of competencies are widely distributed within system engineering, materials, cybernetics, as well as different weapon platforms (Kongsberg, 2011).

The defence firm Nammo was not actually established until before 1998, however, it has existed under various names from as early as 1896 at Raufoss (Eger, 2009, p. 11). Nammo has always been mainly devoted to the production of ammunitions, but is also developing highly advanced competencies within material technologies and rocket motors for space and military applications (Nammo, 2011).

The Bergen based telecom firm Nera, were in 2011 bought by the Israeli company Ceragon Networks (Karlsen, 2012). Nonetheless, Nera still focuses on their same range of products and services within wireless communication. Although, with less product developments towards military applications than before. Even so, the firm is still one of the world leading enterprises on wireless backhaul[29] (Karlsen, 2012).

Sensonor on the other hand has taken an eclectic position between serving military and civilian customers. The firm develops high precision sensors as well as thermal imaging technologies (FSi, 2013). By that the firm develops these products, they could practically be considered as a civilian supplier as they supply military customers and civilian markets with their products.

[28] Under the name of 'Kongsberg Våpenfabrikk'

[29] 'Backhaul' is a term used on the type of transfer of data between stations that forms a communication grid. This type of communication technology is especially advantageous in remote and harsh environments (Karlsen, 2012).

The last firm, Nacre, was as noted in the methodology a spin-off from SINTEF in Trondheim (Dragland, 2007). After Nacre experienced great success in developing acoustical products for the Norwegian, Swedish, and US armed forces, Nacre was bought up by the French company Bacou-Dalloz in 2007 (Dragland, 2007). Today the firm has changed owners yet again, now to Honeywell. Honeywell together with researchers at SINTEF are continuing to further develop their main technologies within acoustics. The key respondent whom I interviewed is still working on development of their product line.

## 6.2 Extent of Dual-Use Technology

To answer the first research question, of what is the extent of defence–civilian spillovers from the Norwegian defence industry to civilian sectors, the interviewees have been asked whether they can recollect any examples of such, and how these have come about. The examples of spillovers contribute to show that dual-use technologies do not only spread through patent publications, but through various means. Some defence–civilian spillovers are deliberately directed towards civilian industries, while others indirectly spill over.

Furthermore, the amount of spillovers varies between the firms, and this variation is related to the firm's knowledge bases and their size. Both Nammo and KDA have deliberately routed several military technologies towards civilian applications. The variety of these applications reflects the broad technological competence bases inherent in these two firms. It would also seem that they are conscious about the potential civilian applications of what they develop.

Considering the three smaller firms, Nera, Sensonor, and Nacre. These firms have several examples of dual-use technologies that contribute to argue extent of defence–civilian spillovers of dual-use technology. Nonetheless, the numbers of dual-use examples are considerably fewer than from the two larger defence firms above. Moreover, the opinions vary between the informants whether the examples of spillovers is a result of intentional marketing or an indirect consequence.

### 6.2.1 Kongsberg Defence and Aerospace

Based on the information collected from the interview, KDA is the firm with most clear examples of dual-use technologies. The interviewee, the Vice President of Marketing and Business Development at KDA mapped out numerous examples of such. One of the interesting findings from the interview is that the informant argued that whenever KDA possessed technology with dual-use potential, they often took an active role in pushing the technology towards civilian applications. This suggests that defence–civilian spillovers could sometimes be quite deliberate.

One example, which you today can find in nearly all seagoing vessels, was a system actually developed as a military product by KDA. Moreover, this type of system has also been partly patented, and more than well cited worldwide. The product is what they call ‘dynamic positioning systems’. According to the informant, in the early 1970s they developed a system for the Norwegian Navy’s torpedo boats, which were to filter massive amounts of information about the conditions at sea. Thus in order to keep the weapon systems at an exact point while engaging targets at speed. The same type of principles behind this product was later used in civilian vessels. By instead of applying this for canons it was constructed for ship thrusters. Thus, keeping the ship at an exact point at any time, no matter what conditions at sea. This product is now widely used in the civilian shipping industry, but also in the offshore oil industry. Moreover, the informant comments: ‘These days cruise ships also install dynamic positioning systems in order to meet restrictions in use of anchors in vulnerable areas. The majority of these systems are from Kongsberg’ (VP Marketing and Business Development, KDA).

In several of the examples KDA seems to have taken a quite active role when technologies have been believed to have more broad spanning areas of application. Even with applications that do not appear to be initially that apparent.

> One time we focused our attention towards large screen LCD technology. The problem was that those big screens on football stadiums and outdoor arenas didn’t work properly. For example PSV Einhoven had this screen produced by Phillips, but very often in rain or fog the screens malfunctioned. But at that time we were producing electronics for the F16 using special production- and coating technology. When we applied this technology in those screens, they worked. […] We didn’t succeed businesswise in this segment, however, that was due to other reasons (VP Marketing and Business Development, KDA).

Another example of dual-use, whereas similar examples are evident also from the US defence industry, is technologies from the production of military aircrafts. In the USA many developments in jet engine technology or knowledge on swept-wing airframes paved the way for later civilian applications (Mowery, 2010, p. 1237). In the 1970s KDA were developing parts for gas turbines as part of the offset agreement on the F16 programme. The knowledge and technologies generated from this involvement was later sold to Volvo Aero that produced parts for civilian aircrafts. As the informant at KDA comments: 'Today, whenever you are out flying in an Airbus or Boeing machine, then you should know that in the majority of these aircrafts you will find engine parts from Kongsberg' (VP Marketing and Business Development, KDA).

### 6.2.2 Nammo

The interview of the Special Advisor from Nammo offered several examples of dual-use technologies, where some are traceable through the patent data. Nammo do also seem to have taken an active role in targeting military technologies for civilian applications. However, the examples that the informant presented does not reflect as broad technological knowledge base as KDA above. Nonetheless, the examples of dual-use technology are consistent with the expertise Nammo holds in material technologies.

The first example was commented above in the quantitative analysis as the aluminium alloy technology used in the M72 anti-vehicle weapon, which received broad interest from the civilian car industry. The interviewee from Nammo remarked that the project on the M72 resulted in that they developed unique competencies in advanced aluminium alloys from constructing the propellant engine of this weapon. The weapon itself achieved great success, and has been used in most modern conflicts today, like in Iraq and Afghanistan (Eger, 2009). On the civilian side, the success of this alloy technology also became prevalent. 'The knowledge behind this engineering was transferred to car bumpers, steering systems, and wheel suspensions, that were adopted into the car manufacturing industry […] This has become a valuable market' (Special Advisor, Nammo).

It would seem that the industrial environment present at Raufoss, with a military enterprise and several civilian firms have had a synergetic effect that lead to civilian use of military technologies. The informant commented that there even was a strategic thought behind the military production at Raufoss, that technologies with some civilian potential should be further developed.

Another example of spillover is of composite technology. The informant remarked that the developments on the ASRAAM missile lead to new advanced knowledge on composite structures. The missile was never sold, however, the composite technology was further applied to pressure resistant containers for electronics in military aircrafts. This high endurance technology was later routed to a composite firm at Raufoss, called RAGASCO. Today, the same composite technology is used in propane containers that one would use to supply a grill or a stove (Eger, 2009, p. 243). Furthermore, the competences in material technology at Nammo have resulted in a variety of other types of civilian applications. '[Like] brasses from bullet casings and projectiles, this set the developing stages for several products within water- and gas distribution' (Special Advisor, Nammo).

### 6.2.3 Nera

According to both the informants from Nera, the company's best-known example of dual-use was developed with considerable assistance from its contractor, the Norwegian Armed Forces. The military involvement paved the path for the technological innovation. The later civilian spillover of their communication technology was a more indirect consequence rather than deliberate marketing. Moreover, one of the informants emphasised that today, civilian developments have outstripped military innovations in communication technology. This have lead Nera to focus more towards civilian markets.

In 1950 Nera won a contract from FFI to construct Norway's radio relay system to improve the military communication (Skogen, 2003). This work revolutionised the communication network in Norway, and achieved great success for Nera in a multitude of export contracts worldwide. 'The initial developments were intended for military usage, however, the radio lines we developed actually formed the basis for the first television broadcasts in Norway' (Former Sales Director, Nera). Moreover, the radio relay links were built in several NATO countries throughout Europe and were quickly adapted to serve civilian purposes.

As the communication technology evolved over time Nera discovered that by following the dual-use applications in civilian markets they would better cope with the technological developments globally. Thus, as Molas-Gallart and Sinclair (1999, p. 661) commented, the civilian developments in ICT's have by far outstripped military developments. This is emphasised by both the informants from Nera. 'The civilian demands today results in much faster developments at lower prices than one will ever experience from the military side. The civilian market has surpassed' (Former Sales Director, Nera). Nevertheless, according to the current Sales Director, Nera/Ceragon delivers communication equipment to military customers worldwide, but these products often only differ from civilian products by encryptions. Nonetheless, these communication specifications and components are still of high interest for civilian industries as the patent analysis has revealed.

### 6.2.4 Sensonor

Sensonor have taken a heterogeneous position in the market, developing products for both military and civilian customers. The informant from Sensonor, the Vice President of Marketing and Strategic Sales, explained that this strategy enables the firm to easily direct military innovations towards civilian applications.

Sensonor's current product range has a multi-use aspect (see chapter 3), by that some of the technologies are so generic that it needs little or no adjustments to be applied for military or civilian purposes. However, they have also developed products for military use that have been subsequently spilled over to civilian appliances. According to the informant at Sensonor they recently developed a special gyro system for a military customer that has by far surpassed previous military products. This product is currently being redesigned for civilian applications.

The interviewee explained that by formally considering themselves as a 'civilian contractor', they avoid legally binding export regulations that they experience to inhibit the technological capabilities of a product. This has been especially advantageous in the American defence market – By that the firm has chosen this kind of strategy, the informant argues that their products are often inferior to many other defence applications, and are thus potential dual-use applications for civilian sectors.

### 6.2.5 Nacre

Nacre's success can in large parts be explained by one single product, an earplug. The Research Director at SINTEF ICT, that was one of two developers in Nacre, remark that the product was continuously directed towards civilian applications, but with little success. It was not until their product had been fully developed and proved in harsh environments that they experienced it to spill over to civilian applications.

The development of this specialised earplug system started in 1989 in a research community in Trondheim (Dragland, 2007). The scientists' competence on advanced acoustics paved the way into developing an intelligent earplug based on noise-cancelling techniques. This product (known as 'HCOM', according to the informant) was directed towards soldiers on the battlefield and was later sold to both the Norwegian and Swedish armed forces, but also to the US Marines through a 200 million NOK contract in 2006 (Dragland, 2007; Research Director, SINTEF ICT).

The informant remarked that Nacre attempted to actively direct their digital earplugs towards civilian industries, because of the obvious dual-use applications of their product. However, this did not seem to go as easy as they had imagined. The Norwegian oil and gas enterprise Statoil and other firms were interested in the early developments in the mid 1990s, but pulled out due to the high costs. In fact, Nacre and their investors spent about 120 million NOK on developments, and it was not until they sold their product to the military (Dragland, 2007). Where its effects were demonstrated that civilian firms became interested for other applications of the product. Today, the technology of this product is used in medical technology and in hearing applications in heavy industries. The informant notes that it has also found uses in the offshore oil and gas industry:

> Honeywell have now produced several earplug-sets that have been called QP100EX for the civilian offshore market. 'EX' so that it can be used on locations with flammable gas. […] Moreover, Statoil has now built up a database that registers the sound exposure of their employees on the platforms with this earplug, and this product is in the process of being implemented on platforms today (Research Director, SINTEF ICT).

## 6.3 Explanatory Factors of Dual-Use Technology

The four explanatory factors, external cooperation, technological breadth, innovative capabilities, and civilian orientation, were all assumed to affect defence–civilian spillovers. However, there are more to these factors than the hypothesised effects. By answering the second research question of which factors could explain the pattern of spillover, the interviews revealed that the factors are more complex, and that aggregated indicators will only provide a partial picture of the decisive factors. Moreover, some of the interviewees added that additional contributing aspects should be considered.

The qualitative interviews have questioned the six representatives from the five different defence firms of what their opinions are of how the spillovers come about. The questions are related to the four previously mentioned factors, as shown in figure 6.1.

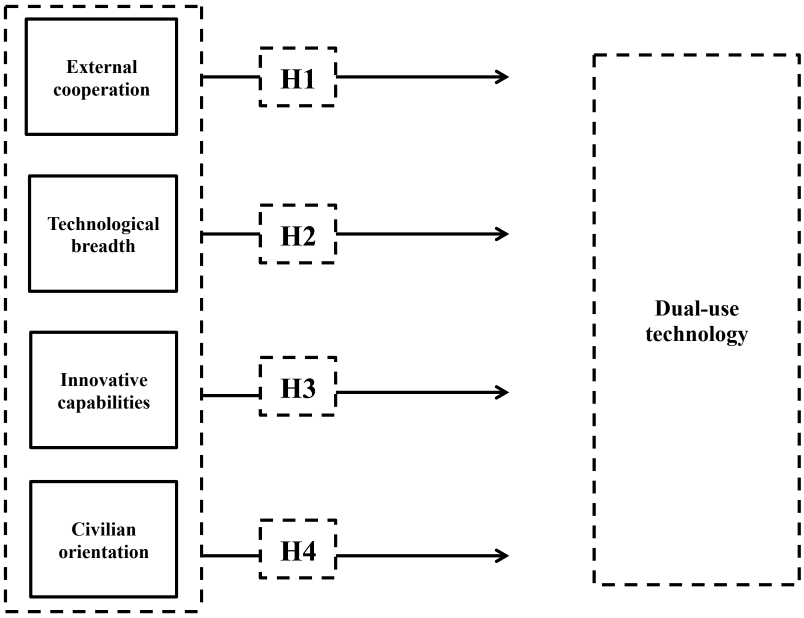



**Figure 6.1** The explanatory factors for dual-use technology.

### 6.3.1 External cooperation

The hypothesis (1) that was set for this explanatory driver was that increased cooperation with external firms should affect defence–civilian spillovers. The opinions from several of those interviewed were that cooperation with external firms have been very important in developing several technologies that have spilled over to civilian applications. However, the views on what type of external firm or organisation vary greatly. Some of the respondents considered the importance of research institutes for developing dual-use technologies, while others civilian firms. The respondents from KDA and Nammo emphasised also the importance of collaborations in terms of exchange of personnel. Nonetheless, most representatives said that collaboration with export clients (measured in the statistical analysis) seldom resulted in spillovers.

There is little doubt that some types of cooperation have played importance in the development of military technology, which has later been applied for civilian use. One external organisation that has been highly important to several of the firm is the Norwegian Defence Research Establishment (FFI). Representatives from Nammo, KDA, and Nera emphasise that the initial collaborations with FFI have contributed to dual-use technologies.

Examples are Nera's radio relays, KDA's underwater vehicle HUGIN, as well as several small innovations in material technology from Nammo. Moreover, to Nacre, the research organisation SINTEF was the main source of competence for the development of Nacres digital earplugs. As remarked above, Nacre was even a spinoff from SINTEF, and today Honeywell collaborates with SINTEF to further develop the product (Research Director, SINTEF).

Nonetheless, when considering cooperation with other firms, especially civilian, the views of its benefits vary among the firms. On one side, KDA's representative emphasised especially that the initial developments on HUGIN battery technology with FFI was a contributing factor to its development. Moreover, the involvement in the project by Statoil has given the vehicle broad civilian use. Today, HUGIN is configured to look for mines, as well as scan the topography of the seabed, and has found its use by both the military and civilian firms.

> There is this Kongsberg owned US firm that supported the search and rescue team with an autonomous underwater vehicle, similar to HUGIN, searching for the crashed Air France flight 447 off the coast of Brazil. This particular vehicle is capable of diving as deep as 6000 meters […] This Kongsberg Underwater Vehicle found the remains of that aircraft (VP Marketing and Business Development, KDA).

Moreover, Nammo remark that the cooperation with Årdal-Sundal Productions (currently known as Hydro) played an important role in supporting the manufacturing of their specialised aluminium alloys that were used in the previously mentioned M72, which had a dual-use impact on the car manufacturing industry.

On the other hand, cooperation with other firms have not always fulfilled their hopes, nor generated dual-use technologies. The representative from Nacre remarked that over a period of over 10 years they attempted to cooperate with civilian clients in their technological developments. Both the Swedish mobile firm Ericsson and the Norwegian oil company Statoil were invited. However, it never resulted in any great success. In fact, the interviewee comment: 'It was not until the Norwegian and the Swedish military involved themselves that things started rolling' (Research Director, SINTEF ICT). Furthermore, even though Nammo have had successful collaborations with civilian firms, the interviewee remarked that they have also had several attempts of involving civilian firms in their developments, which sometimes have lead to little success. Indicating the experience of collaborating with other firms is varied.

The informant from Nammo commented that those cases where one have seen military technologies spill over to civilian applications, the significant contributing factor have been the transfer of competent personnel. This transfer, of the tacit knowledge, also became clear from the interview of KDA. Currently KDA have routed a military command and control system (a monitoring system that enables a user to take qualified decisions through calculations of many external factors) in to their oil and gas branch at Kongsberg, which will try to implement this system for civilian use. The implementation of this system that they call Environmental Monitoring System is lead by personnel whom previously have been deeply involved in the military developments.

When the firm representatives were questioned about cooperation with export clients, several of the interviewees remarked that nearly all prior collaborations with export clients had been with military customers. The response from the interviewees at Nacre, Nammo, and KDA, indicate that such collaborations have led to more specialised military technologies, with great success. Nonetheless, these technological developments have seldom evolved into subsequent dual-use technologies. This supports Stowsky (2004), who argued that this type of technological collaboration, which he terms 'shielded innovation' (p. 258), actually inhibits dual-use technologies. The respondent from Nacre argued that this is a result of the military specifications, which are so specialised that it often becomes difficult to find civilian applications for it. In their own cooperation with the US Marines, the research director remarked: 'The military specifications developed were never transferred into any subsequent product that could be used in offshore industries, even if the former is located in a harsh environment' (Research Director, SINTEF ICT).

It would seem that the effect of cooperating with other firms or organisations is varied. There are some examples where such cooperation has led to successful civilian applications, but there are still others that indicate the opposite. Especially the cooperation with export clients seems to support the quantitative findings, which were negative. Another aspect that did arise from the interviews was that the defence firms often took an active role in developing military technologies for civilian applications. Not through initial cooperation with clients, but with transfer of competent personnel. Moreover, cooperating with research institutes (like SINTEF or FFI), an indicator that was not measured in the quantitative study seems to have had an effect on spillovers.

### 6.3.2 Technological breadth

This factor was hypothesised (2) to affect defence–civilian spillovers of dual-use technology, when technological breadth is increased. Of the examples of dual-use technologies presented by the informants, many of these are a result of a combination of several competencies rooted in different knowledge bases, and/or different technologies. The qualitative information indicates that the measure of IPC-classifications in a patent application is not the only indicator of technological breadth. Moreover, the spin-in of technology to defence firms from civilian industries have the potential to increase this breadth, which sometimes affects subsequent civilian benefits as well.

From the interviews it would seem that there are some differences between the defence firms in terms of technological competencies, and how they use it in developments. Firms like Nacre, Sensonor and Nera, admit that they rely on quite deep and specialised knowledge bases in their developments. They are also less apt to incorporate other products or technologies than KDA and Nammo. However, even though these specialised knowledge bases might be perceived as narrow fields of competence, they consist of several scientific specialisations. This enables their technological developments to be based on a combination of multiple competencies within electronics, communication as well as acoustics. Thus, increasing the technological breadth of their products. For example, even if Nacre considered the developments of their digital earplug deep within the knowledge of acoustics, their product was a combination of advanced ASIC technology, signal processing and electronics. Moreover, due to the firm's highly advanced products they seldom added complementary technologies from other industries or used civilian components, as they develop this themselves.

On the other hand, Nammo and KDA do combine many technologies, both components and competencies in their products. Especially KDA tend to use civilian technologies in their products if the commercial markets can deliver reliable and cheaper components. This is one of the clear traits of the so-called spin-in paradigm argued by some authors (Alic et al., 1992; Brandt, 1994).

> '25-30 years ago we produced the computers, developed our own SW language and compilers, well everything. Today we buy it, from those that know it, and civilian industries are getting increasingly good at it […] [W]e integrate it into systems through system engineering. System Engineering is the key word' (VP Marketing and Business Development, KDA).

Both KDA and Nammo do also integrate different types of technologies rooted in various knowledge bases. Nammo that have been traditionally involved in materials are also using various technologies like advanced electronics and sensors in many of their products. KDA have had several successful dual-use products that were constructed from the utilisation of many technologies. Examples are the previously mentioned underwater vehicle HUGIN and their dynamic positioning systems. Today, KDA is currently integrating laser technology from the military industry with pyro optic fuse technology towards drill and well applications in the oil and gas industry.

All firms considered, even if they use narrow technological knowledge like Nera, Nacre, or Sensonor. Or combine civilian and defence components like Nammo and KDA, the results indicate that the incorporation of various technologies and competencies do support Avadikyan et al. (2005) conclusions, that that the technological breadth used in the development of a product will affect defence–civilian spillovers.

### 6.3.3 Innovative capabilities

The innovative capabilities of defence firms in other nations industries have shown to affect defence–civilian spillovers (Mowery, 2010). This is also the hypothesised (3) effect for the companies in the Norwegian defence industry. Several of the respondents accentuated that there is no difference when it comes to the Norwegian context. The firm representatives remark that investments in R&D, especially on development, are essential in order to sustain their competitiveness. Moreover, the current sales director at Nera believed that an additional factor to them was highly competent employees. Combined, these capabilities have been vital for new technological inventions that have spilled over to civilian applications.

The Norwegian defence industry has been characterised as an industry that is far more innovative compared to other domestic industries (Fevolden et al., 2009). From the interviews it stands clear that among the defence firms investments in R&D as well as their workforce are important factors in the development of new innovative products. Seemingly there is no perceived difference of the capabilities importance among the firms.

The current sales director of Nera underlines that their R&D investments as well as their workforce with over 100 dedicated engineers are indispensable factors to retain their market shares and to compete. Nacre also emphasised the importance of such dedication. Nacre spent over 120 million NOK on R&D, which they deemed as quintessential for the development of their digital earplug. 'Developing this product was extremely expensive [...] We had to make everything from scratch, and for every trial of production we needed 5 million NOK' (Research Director, SINTEF ICT).

The importance of investments in competent workers as well as in R&D is remarked by the Special Advisor from Nammo as: 'Definitive, without our investments on developments it all would have ended.' Moreover, the interviewee comment that public measures are important to maintain their developments, even though they have substantial privately funded R&D. 'By this support we have been able to develop technologies to a high level, which indirectly have resulted in spillovers to civilian industries' (Special Advisor, Nammo). However, the respondent from Nacre disagrees on the importance of such publicly financed R&D. Their experience was that in order to receive this kind of support they had to have an almost fully developed product. According to the informant from Nacre, public measures were more focused towards other industries. Therefore, Nacre was reliant on private investors as venture capitalists. As time have shown, these investments was no unfortunate decision, as one of the investors Ferd Venture, provided Nacre with 15 million NOK, and two years later earned 225 million NOK after the sale to Bacou-Dalloz (Research Director, SINTEF ICT). Nonetheless, all firms considered, these investments as well as a competent workforce is considered imperative in developing new innovative products, as several have become dual-use technologies later on.

Mowery (2010, p. 1236) argued that a company's innovative capabilities are vital factors contributing to developing advanced technologies, technologies that appear to have greater dual-use potentials early in the development phase. From the interviews, there are no clear tendencies as to when, in the life-cycle of a technology, other industries have indicated their interest. The Special Advisor from Nammo commented that the developments of their composite structures demanded a long development process before it finally found its civilian applications. Nera on the other hand remarked that they extensively used patenting to protect their products, as others firms are very interested at an early stage. Nacre takes a sort of a middle ground by that civilian industries were interested at the beginning, but quickly retained their interest as soon as they discovered the development costs for their specific use. Thus, there are only some indications that technologies at an early stage of development are more apt to be become dual-use technologies as some other authors have claimed (see Reppy, 1999; Mowery, 2010).

### 6.3.4 Civilian orientation

Defence firms in the Norwegian defence industry are considered relatively heterogeneous, with varying focus towards defence and civilian customers (Blom et al., 2012). This factor hypothesised (4) that increased civilian orientation would affect defence civilian-spillovers positively. The interviews support that civilian orientation contribute to drive defence–civilian spillovers, based on the counterfactual indication that defence focus hinders such spillovers.

In the USA, Mowery (2010) argued that increased revenues from sales of specific military products would create incentives for defence firms to further develop specialised military products. Subsequently this would lead to a trait of preferring defence markets, which would decrease the potentials of generating technologies with more general applicability, thus generating fewer dual-use technologies (Mowery, 2010).

In subsection 6.3.1 above, it was remarked that the specifications Nacre did in order to sell their product to the US Marines demanded certain specifications that later had few applications for civilian use. Moreover, the informant from Nacre commented that the developers for long wished to adapt their product towards civilian application while they adjusted it for military usage. However, the management of Nacre opposed since they were set to focus towards those customers that would secure the company's revenue. 'When the military customers got in we only though about defence and soldiers. We spent hours sitting in tanks' (Research Director, SINTEF ICT).

Other firms seem also to emphasise the devotion to specify their technologies in order to fulfil the requirements from their military customers. The Sales Director at Nera remarked that the military specifications have been far more detailed than by others. With military customers, there is often an offset agreement, which has to be fulfilled. According to the Sales Director this is often a demanding challenge to the enterprise.

Furthermore, by focusing developments towards specialised military requirements the technologies are often constricted by legal obligations of secrecy. The strategic decisions to keep technologies secret are certainly an advantage to avoid that potential enemies or competitors gains access to a specific technology. Nonetheless, it decreases the openness around the developments that limit the possibility of civilian interest. It certainly does not lead to patenting. Subsequently inhibiting dual-use applications.

Thus, one solution to this problem of becoming too dependent on defence-related revenues could be to increase more developments towards civilian sectors within a firm. However, Nammo have attempted this and encountered some institutional problems.

> The biggest issue of having a mix of civilian and military divisions within a firm was that the organisation had to respond to customers with very different requirements and cultures. The military customer was often perceived as to slow, inefficient and low on productivity, and the automotive industry was very focused on cost reduction and efficiency. […] That is why we separated the civilian and defence divisions (Special Advisor, Nammo).

Today, Nammo is purely devoted to military productions, nonetheless, whenever they encounter technology that they believe could have some potentials of having dual-use for civilian industries they attempt to direct this towards civilian firms. RAGASCO and their composite propane tanks is one of the most recent successful examples.

KDA is also mainly devoted towards military developments. However, the firm representative remark than whenever they develop technologies with potential dual-use application, the technologies are guided towards the civilian branches of the main enterprise. Technologies that are suitable for oil and gas productions are channelled towards Kongsberg Oil and Gas Technologies, ship technologies are directed towards Kongsberg Maritime. Then again, civilian technologies with potential military applications are guided from the former entities to back KDA.

## 6.4 Summarising the Results and Analysis

To answer the first research question[30], to what extent defence–civilian spillovers of dual-use technologies can be observed, the interviews uncovered several examples of defence–civilian spillovers from the Norwegian defence industry. However, the amount varies between the firms. The largest defence firms, KDA and Nammo, which are the dominant firms in the industry, have several examples of such spillovers. Of these, there are a variety of applications that reflects these firms' broad technological competencies.

Moreover, the former companies also take a more active role in routing potential dual-use technologies towards civilian industries than the three smaller firms. The interviewed small and medium-sized defence firms in the industry have a narrower product range compared to the larger ones, and have therefore fewer examples of dual-use technology. Nonetheless, Nacre, Nera, and Sensonor has produced military technologies with substantial

[30] The results are summarised in main points in table 6.1 below.

civilian interest, and this could be partly explained by that they tend to take a more pragmatic approach by supplying both military and civilian sectors. Because by doing this they are likely to integrate relevant civilian capabilities in their defence technologies, that eases later civilian interest, which is closely linked to what Verspagen and Loo (1999, p. 226) argued.

The interviews exposed that the distribution of international citations[31] seen in the former chapter could somewhat be explained by that some of the countries with substantial spillovers are countries where Norwegian defence firms focus their activities in. Regarding sales of both military and civilian technologies. KDA and Sensonor have divisions in multiple countries, but focuses especially on the US and the Asian market. Nammo, Nacre, and Nera devote much attention towards the US but also the European market. These regional focuses could be explained mainly by numerous offset agreements. Nevertheless, some of these regions also have dominant civilian industries with competencies closely linked to what these firms deliver for military customers. For example: The Kongsberg Group have located their civilian branch, Kongsberg Maritime, in Asia to provide electronic control systems for the ship manufacturing industry. The systems they provide are originally defence systems, for example dynamic positioning.

Responding to the second research question[32], of what factors could explain the pattern of spillover, all firm representatives were encouraged to assess whether the proposed factors had affected spillovers from their firm. Additionally, if there were other features they believed to have been more important. The factors presented in the theoretical chapter were somewhat broad and discussed dynamic influences, and the former subsections have tried to reflect that. The qualitative inquiries showed that the perceptions of these factors are more complex, particularly the cooperative factor.

In the quantitative analysis the cooperative hypothesis had an expected positive outcome, but this was not supported. As the interviews have shown, cooperation with different types clients are not always a relevant factor for dual-use – especially not for export clients. But what the interviews emphasised was that cooperation with research institutes had been important, in addition to the transfer of competent personnel.

On the other hand, the factors addressing firm capabilities and technological breadth were supported as important in generating new dual-use technologies. Moreover, other contributing elements than the number of IPC-classifications were considered as important for defence–civilian spillovers. Hence: both the combination of competencies from different

[31] International citations were used as a control variable (*DINT*) in the regressions.
[32] The results are summarised in main points in table 6.1 below.

knowledge bases and technologies, but also the aspects of spin-in from civilian industries.

Finally, the interviews support the dangers of producing specialised military technologies by that this positions the firm further away from civilian markets. These results support the counterfactual argument that civilian orientation affects defence–civilian spillovers positively. Consequently, continuing with mainly military productions might contribute to enforce the institutional divide that Markusen and Yudken (1992) called 'the wall of separation'.

**Table 6.1** Summary of results from the interviews

| | **Kongsberg Defence and Aerospace** | **Nammo** | **Nera** | **Sensonor** | **Nacre** |
|---|---|---|---|---|---|
| **Extent of spillovers:** | | | | | |
| | - Several examples<br>- Various technologies<br>- Intentional spillovers | - Several examples<br>- Material technologies | - Radio relays<br>- Communication technology | - Multi-use<br>- Sensors and gyro's | - One product<br>- Audio technologies<br>- Broad impact |
| **Explanatory factors:** | | | | | |
| **External cooperation** | - Importance of FFI<br>- Collaboration with Statoil on HUGIN<br>- Cooperation with export clients has often led to very specialised products with little dual-use.<br>- Exchange of competent personnel | - Importance of FFI<br>- Cooperation with Årdal-Sundal (Hydro) on aluminium alloys.<br>- Other collaborations with civilian firms have ended in little success<br>- Exchange of competent personnel | - Importance of FFI on radio relays.<br>- Little cooperation today<br>- Influenced by competitors | - Influenced by competitors | - Importance of SINTEF |
| **Technological breadth** | - Broad knowledge base<br>- Combine a variety of components and technologies<br>- Combines both military and civilian technology in products | - Combine a variety of components and technologies | - Employs deep and specialised knowledge | - Employs deep and specialised knowledge<br>- Utilises civilian technology | - Employs deep and specialised knowledge<br>- Broad competencies in acoustics |
| **Innovative capabilities** | - R&D is essential | - R&D is essential<br>- Values public financed R&D | - R&D with emphasis on 'D' is considered essential<br>- Highly competent employees | - R&D is essential | - R&D is essential<br>- Relied on venture capitalist rather than publicly financed R&D |
| **Civilian orientation** | - Dominant military focus.<br>- Guides potential spillovers to civilian branches, and receives civilian technologies from the former | - Very difficult to focus on both markets. Has retained a military orientation. | - Military developments become constrained by secrecy. Focuses today more on civilian developments | - Heterogeneity gives the firm advantages in both markets, and affects dual-use | - Defence development hampered civilian applications |

# 7. Conclusions

Earlier studies of defence–civilian spillovers of dual-use technologies from defence industries have focused primarily on large dominant industries during and in the aftermath of the Cold War. This thesis has shown that the Norwegian defence industry currently develops multiple technologies that are used in civilian applications worldwide. Some of these technologies have, like other military innovations, paved the way for civilian innovation. The thesis has also shown that even today, when much technological innovation is led by civilian industries, defence developments affect civilian technologies. This indicates not only that Norway's defence industry is a competitive industry in international military markets, but also that the development of military technologies often has broader civilian benefits. Furthermore, certain capabilities and strategies of a defence firm have shown to affect defence–civilian spillovers.

## 7.1 Main Findings

Even though the Norwegian defence industry is very innovative and has high expenditures on R&D, the industry has received modest academic attention, and, to my knowledge, there have been no studies of dual-use technology. This thesis has sought to fill that gap, by employing quantitative patent analyses and qualitative interviews to answer the following research questions:

(i) What is the extent of defence–civilian spillovers from the Norwegian defence industry to civilian sectors?

(ii) What factors explain this pattern of defence–civilian spillover?

### 7.1.1 Extent of dual-use technology

This thesis has offered supporting evidence, from quantitative as well as qualitative analyses, of the existence of defence–civilian spillover of dual-use technologies in Norway. In answering the first research question, five important findings have been made.

(1) The answer to what extent defence–civilian spillover could be observed is limited by both time and the lack of comparative studies. Nonetheless, it is clear that the extent of dual-use varies among defence firms. Both the large multi-technology firm Kongsberg

Defence and Aerospace and the munitions producer Nammo have long experience in active transfers. The more civilian orientated defence firms Sensonor, Nacre, and Nera can show fewer examples of dual-use, although they have even more citations on average than the larger companies.[33]

(2) The technological fields cited in civilian applications are mostly the same fields as those cited in military patents. Thus, defence products characterised as for example measurement technologies are used in civilian applications within the same field. This supports Verspagen and Loo (1999) that argued that inter-sector spillovers could be observed especially where there is similar technological use in another sector. However, less predictable spillovers were also discovered, like the use of dynamic positioning – from gun turrets to ship thrusters, and process technology on aluminium alloys in a rocket launcher to car bumpers.

(3) Defence technologies are widely used in civilian sectors outside Norway, as the international distribution of citations is substantial when compared to domestic citations. The US is the country where most dual-use technologies are applied, followed by several European countries. According to the interviews, this is a result of close collaborative ties to other nations industries through offset agreements, NATO membership, as well as strategic localisation of foreign divisions of the defence firms.

(4) The distribution of civilian citations over time (figure 5.4 in chapter 5) showed that the amount of defence–civilian spillovers have actually increased in the latest decade – This is contrary to what some other scholars have claimed. These results indicate that military technology developed by the Norwegian defence industry is exerting an increasing influence on civilian innovation.

(5) Finally, this study has shown that dual-use can be observed in the Norwegian defence industry, and that the empirical approach of collecting patents and citations to reveal such tendencies is effective, as indicated by an earlier study (Acosta et al., 2011).

[33] See appendix 4, table 4.1 for the most civilian cited defence firms (commented in chapter 4).

### 7.1.2 Explanatory factors

This thesis has, by using both quantitative and qualitative approaches, tested whether several explanatory factors could explain the pattern of defence–civilian spillovers. I find that four explanatory factors affect spillovers of dual-use technology: (1) external cooperation, (2) technological breadth, (3) innovative capabilities, and (4) civilian orientation.

(1) The statistical results showed that cooperating with other firms affected subsequent civilian use negatively and significantly – thus, *not* supporting the hypothesis. However, the interviews revealed that the effects of collaborating with other firms are varied. For some companies, cooperation with civilian firms has been a contributing factor for spillovers; for others it has not. The results show that collaboration with external firms like domestic, export clients or civilian firms are not crucial factors affecting spillover. On the other hand, it has been argued that collaboration with research institutes have affected several defence–civilian spillovers. Moreover, some of the interviewees emphasised collaborations in the form of transfer of competent personnel as important.

(2) Both the statistical and the qualitative results demonstrate that the explanatory factor of technological breadth affects spillover. Integrating civilian technologies, components and scientific knowledge in product development can bring substantial possibilities for creating technologies with spillover potentials. Therefore, this thesis supports Hall et al. (2002), that increased technological breadth will affect the prospects for spillover.

(3) The combined results from both the statistical analysis and interviews confirm that firms' innovative capabilities are decisive elements as regards to defence–civilian spillovers. Interviewees underscored the importance of R&D in product developments, but also the importance of highly competent employees. The statistical results also showed that the R&D intensity of the firm was a strong significant contributor to spillovers. It might seem to be a linear argument that by investing in R&D a company will achieve new dual-use technologies with civilian benefits. A company's R&D intensity will not always generate radical new innovations, but the chances are that they sometimes will. On the other hand, new technological developments are unlikely to occur if efforts are lessened. Thus a main argument is that defence investments in both R&D and competent workforce will affect civilian usage of defence technologies.

(4) Finally, this thesis finds that the civilian orientation of a defence firm affects the spillovers of dual-use technology. Heterogeneous defence firms with considerable civilian orientation prove to be more proficient in generating spillovers, compared to firms with a

narrower defence focus. The results support Mowery's (2010) observations from the US defence industry. In both empirical approaches, the results show that tracing the path of developing technologies for mainly military customers, thereby yielding higher defence revenues, reduces the potentials of generating technologies with civilian applicability. The reason is that military-specific technologies tend to be highly specialised for military applications with little civilian relevance. Moreover, defence-oriented firms develop technologies within procurement contracts, which often involve confidentiality agreements that act to shield the technologies. Thus, one main recommendation would be to structure a firm strategically towards developing products for both military and civilian customers, as the more heterogeneous companies have indeed done. However, as the respondent from Nammo remarked, restructuring a defence company has proven highly challenging.

## 7.2 Policy Implications

This thesis has several important findings with potentially important implications for future policies. First of all, the spillovers of technologies from the Norwegian defence industry affect industries abroad more than domestic civilian industries. This could affect the instruments directed towards the industry, as public policies result in more international than national spillover. Thus, future policies should encourage domestic firms to take greater advantage of technological developments in the defence industry. This is especially important today as the number of defence–civilian spillovers has been rising. In turn, revitalised and improved policies can be expected to affect value creation among Norwegian enterprises.

The interviews indicated that collaboration with the two research institutes SINTEF and FFI has been essential with regard to several dual-use technologies. Improved policies that encourage collaboration might provide great spillover benefits to civilian industries. The combined expertise could also contribute in fulfilling a main objective of the Norwegian Ministry of Defence to develop new advanced military technologies that would benefit the capabilities of the Norwegian Armed Forces (e.g. radio relays, HUGIN).

The effect of public-financed R&D was emphasised as a substantial factor in producing military technologies with later spillovers over to civilian applications. However, not all the companies report that public-financed R&D is equally accessible. Future policies should therefore aim at improving public-financed R&D to *all* defence firms, and not only the large oligopolistic establishments.

Finally, policies should continue to support defence firms in Norway, as they not only contribute to new military capabilities for the Norwegian Armed Forces, but regional growth and new civilian spinoff companies. This can be observed with the regional clusters at Kongsberg and at Raufoss, with KDA and Nammo, respectively.

## 7.3 Research Implications

This thesis has demonstrated how qualitative and quantitative methods can be fruitfully used for empirical study of defence–civilian spillovers of dual-use technology in the Norwegian defence industry. Future research should attempt to broaden this perspective with comparative studies, but should also investigate the civilian aspects of these spillovers.

To further clarify the extent of spillover, future research should examine other defence industries, especially in Scandinavia, who share geographical closeness as well as similar cultures. It would be especially relevant to compare Norway's industry with the Swedish defence industry in terms of defence–civilian spillovers, not least since the Swedish industry is considered to be much larger and more advanced than its Norwegian counterpart (Castellacci, Fevolden & Lundmark, 2013; Bitzinger, 2003).

Academic discourses on the concept of dual-use would also benefit if future studies examine the role of civilian–defence spillovers, investigating how defence industries adopt and apply civilian technological developments in defence products, and whether these spillovers contribute to circular benefits to both industrial groups.

Following the procedures for collecting empirical data on the Norwegian defence industry as outlined here, future research should further trace the civilian uses of defence technologies, investigating what types of civilian firms use these technologies, and how these firms value the applications of defence developments. Such an approach could contribute to the further development of well-founded policy advice in this important sphere.

## 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.

Alic, J.A., Branscomb, L.M., Brooks, H., Carter, A.B., & Epstein, G.L. (1992). *Beyond Spinoff: Military and Commercial Technologies in a Changing World.* Boston, MA: Harvard Business School Press.

Alic, J.A. (1994). The Dual Use of Technology: Concepts and Policies. *Technology in Society, 16*(2), 155–172.

Amorelli, T. (1996). *Dual Use and Technology Transfer in the Titanium Industry.* The IPTS Report, 4. (pp. 27–30). Seville: European Commission's Joint Research Centre.

Avadikyan, A., Cohendet, P., & Dupouët, O. (2005). A Study of Military Innovation Diffusion Based on Two Case Studies. In P. Lierena, M. Matt & A. Avadikyan (eds), *Innovation Policy in a Knowledge-based Economy: Theory and Practice* (pp. 161–189). Berlin: Springer.

Baxter, J. (2010). Case Studies in Qualitative Research. In I. Hay (ed.), *Qualitative Research Methods in Human Geography* (pp. 81–97). Ontario: Oxford University Press.

Bellais, R. & Guichard, R. (2006). Defense Innovation, Technology Transfers and Public Policy. *Defence and Peace Economics, 17*(3), 273–286.

Bitzinger, R.A. (2003). *Towards a Brave New Arms Industry?* London: International Institute for Strategic Studies.

Blom, M., Castellacci, F., & Fevolden, A. (2011). *Defence Firms Facing Liberalization: Innovation and Export in Agent-based Model of the Defence Industry*. NUPI Working Paper 793. Oslo: Norwegian Institute of International Affairs.

Blom, M., Castellacci, F., & Fevolden, A.M. (2012). The Trade-off between Innovation and Defence Industrial Policy: A Simulation Model Analysis of the Norwegian Defence Industry. *Technological Forecasting and Social Change,* in press.

Bradshaw, M. & Stratford, E. (2010). Qualitative Research Design and Rigour. In I. Hay (ed.), *Qualitative Research Methods in Human Geography* (pp. 69–80). Ontario: Oxford University Press.

Brandt, L. (1994). Defence Conversion and Dual-Use Technology: The Push Toward Civil–Military Integration. *Policy Studies Journal, 22*(2), 359–370.

Breschi, S., Lissoni, F., & Malerba, F. (2004). The Empirical Assessment of Firms' Technological 'Coherence': Data and Methodology. In J. Cantwell, A. Gambardella & O. Granstrand (eds), *The Economics and Management of Technological Diversification.* (pp. 69–97). London: Routledge.

Buesa, M. (2001). Controlling the International Exchanges of Armaments and Dual-use Technologies: The Case of Spain. *Defence and Peace Economics, 12*(5), 439–464.

Carpenter, M.P., Narin, F., & Woolf, P. (1981). Citation Rates to Technologically Important Patents. *World Patent Information, 3*(4), 160–163.

Castellacci, F. & Fevolden, A. (2012). *Capable Companies or Changing Markets? Explaining the Export Performance of Firms in the Defence Industry.* NUPI Working Paper 795. Oslo: Norwegian Institute of International Affairs.

Castellacci, F., Fevolden, A.M. & Lundmark, M. (2013). *How are Defense Companies Responding to EU Defense and Security Market Liberalization? The Case of Norway and Sweden.* NUPI Working Paper, Forthcoming. Oslo: Norwegian Institute of International Affairs.

Cowan, R. & Foray, D. (1995). Quandaries in the Economics of Dual Technologies and Spillovers from Military to Civilian Research and Development. *Research Policy, 24,* 851–868.

Creswell, J.W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Los Angeles, CA: SAGE.

Creswell, J.W., Clark, V.P.L., Gutmann, M.L., & Hanson, W.E. (2003). Advanced Mixed Methods Research Designs. In A. Tashakkori & C. Teddlie (eds), *Handbook of Mixed Methods in Social & Behavioral Research* (pp. 209–240). London: SAGE.

David, P.A., Hall, B.H. & Toole, A.A. (2000). Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence. *Research Policy, 29,* 497–529.

Dowling, R. (2010). Power, Subjectivity, and Ethics in Qualitative Research. In I. Hay (ed.), *Qualitative Research Methods in Human Geography* (pp. 26–39). Ontario: Oxford University Press.

Dragland, Å. (2007, 26 May). Med øre for suksess. *Gemini*. Retrieved December 11, 2012, from http://www.ntnu.no/gemini/2007-05/26-29.htm

Dunn, K. (2010). 'Doing' Qualitative Research in Human Geography. In I. Hay (ed.), *Qualitative Research Methods in Human Geography* (pp. 99–138). Ontario: Oxford University Press.

Eger, P.H.J. (2009). *Rett til himmels: et industrieventyr på Raufoss.* Gjøvik: Alfa forlag.

Espacenet. (2011, 24 March). *Espacenet – Patent Search.* Retrieved 3 December 2012, from http://www.epo.org/searching/free/espacenet.html?hp=stages

Espacenet. (2012, 24 September). *Worldwide Patent Search.* Accessed between 9 and 30 November 2012, from http://worldwide.espacenet.com/numberSearch?locale=e n_EP

Fevolden, A., Andås, H. & Christiansen, J. (2009). *En kartlegging av kunnskap og kompetanse innen forsvarsindustrien i Norge.* FFI Report 2009/01068. Kjeller: Norwegian Defence Research Establishment.

Fevolden, A., Christiansen, J. & Karlsen, E.N. (2011). *Verdiskaping i forsvarsindustrien i Norge – en studie av den industrielle utviklingen på midten på 2000-tallet.* FFI Report 2011/01258. Kjeller: Norwegian Defence Research Establishment.

Fevolden, A., Karlsen, E.N., & Ringdal, E. (2008). *Virkemiddelapparatet og forsvarsindustrien i Norge.* FFI Report 2008/02066. Kjeller: Norwegian Defence Research Establishment.

Fevolden, A.M. & Tvetbråten, K. (2013). The Norwegian Defence Industry – Industrial Development between Foreign Dependence and Self-sufficiency. *Eksport Vooruzheny, forthcoming.*

Field, A. (2009). *Discovering Statistics Using SPSS*. London: SAGE.

Finstad, Ø. (2012, 14. January). Mot strømmen. *Dagens Næringsliv.* Retrieved 17 January 2013, from http://www.ceragon.com/files/12-01-14%20DN%20on%20Ceragon.pdf

FSi. (2013). *Medlemsbedriftene: Sensonor AS.* Retrieved 27 February 2013, from FSi http://www.fsi.no/fsi/medlemmer/sensonor-as/

Fuhrmann, M. (2008). Exporting Mass Destruction? The Determinants of Dual-Use Trade. *Journal of Peace Research, 45*(5), 633–652.

Granstrand, O. (2005). Innovation and Intellectual Property Rights. In J. Fagerberg, D.C. Mowery & R.R. Nelson (eds), *The Oxford Handbook of Innovation* (pp. 266–290). New York: Oxford University Press.

Griliches, Z. (1990). Patent Statistics as Economic Indicators: A Survey. *Journal of Economic Literature, 28,* 1661–1707.

Guillou, S., Lazaric, N., Longhi, C. & Rochhia, S. (2009). The French defence industry in the knowledge management era: A historical overview and evidence from empirical data. *Research Policy, 38*, 170–180.

Hall, B.H., Jaffe, A.B. & Trajtenberg, M. (2002). The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools. In A.B. Jaffe & M. Trajtenberg (eds), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 403–459). Cambridge, MA: MIT Press.

Iversen, A.B. (2011). Kommentar: Kvalitative og kvantitative metoder – Et kontinuum? *Sosiologisk Tidsskrift, 19*, 175–183.

Jaffe, A.B., Fogarty, M.S. & Banks, B.A. (1998). Evidence from Patents and Patent Citations on the Impact of NASA and other Federal Labs on Commercial Innovation. *Journal of Industrial Economics, 46*(2), 183–205.

Jaffe, A.B. & Trajtenberg, M. (2002). Introduction. In A.B. Jaffe & M. Trajtenberg (eds), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 1–22). Cambridge, MA: MIT Press.

Jaffe, A.B. & Trajtenberg, M. (1999). International Knowledge Flows: Evidence from Patent Citations. *Economics of Innovation and New Technology, 8*(1–2), 105–136.

Jaffe, A.B., Trajtenberg, M. & Fogarty, M.S. (2002). The Meaning of Patent Citations: Report on the NBER/Case–Western Reserve Survey of Patentees. In A.B. Jaffe & M. Trajtenberg (eds), *Patents, Citations, and Innovations: A Window on the Knowledge Economy* (pp. 379–401). Cambridge, MA: MIT Press.

Jaffe, A.B., Trajtenberg, M. & Henderson, R. (1993). Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Quarterly Journal of Economics, 108*(3), 577–598.

James, A.D. (2000). The Place of the UK Defense Industry in its National Innovation System: Co-evolution of National, Sectoral and Technological Systems. In J. Reppy (ed.), *The Place of the Defence Industry in National Systems of Innovation.* Occasional Paper 32 (pp. 97–124). Ithaca, NY: Cornell University.

Karlsen, E. (2012, 23 January). Nummer én på trådløs backhaul. *Elektronikk*. Retrieved 20 January 2013, from http://www.ceragon.com/files/Elektronikk_2301-2012_1.pdf

Kelley, M.R. & Watkins, T.A. (1995). In from the Cold: Prospects for Conversion of the Defense Industrial Base. *Science, 268,* 525–532.

Kleinknecht, A., Montfort, K.V. & Brouwer, E. (2002). The Non-Trivial Choice between Innovation Indicators. *Economics of Innovation and New Technology, 11*(2), 109–121.

Kongsberg. (2011). *Annual Report.* Retrieved 26 February 2013, from http://www.kongsberg.com/sitecore/shell/Controls/Rich%20Text%20Editor/~/media/KOG/Files/Investor/Annual%20reports/2011/KOG_AnnualReport_2011.ashx

Kongsberg. (2013). *History*. Retrieved 25 February 2013, from Kongsberg http://kongsberg.com/en/kog/aboutus/history/

Kulve, H. & Smit, W.A. (2003). Civilian–military Co-operation Strategies in Developing New Technologies. *Research Policy, 32,* 955–970.

Kvale, S. (2007). *Doing Interviews.* London: SAGE.

Levin, R.C., Klevorick, A.K., Nelson, R.R. & Winter, S.G. (1987). Appropriating the Returns from Industrial Research and Development. *Brookings Papers on Economic Activity, Special Issue on Microeconomics, 1987*(3), 783–831.

Lichtenberg, R.F. (1995). Economics of Defense R&D. In K. Hartley & T. Sandler (eds), *Handbook of Defense Economics.* (pp. 431–457). Amsterdam: Elsevier.

Markusen, A. & Yudken, J. (1992). *Dismantling the Cold War Economy.* New York: Basic Books.

Maurseth, P.B. & Verspagen, B. (2002). Knowledge Spillovers in Europe: A Patent Citation Analysis. *Scandinavian Journal of Economics, 104*(4), 531–545.

Maurseth, P.B. & Svensson, R. (2012). *Micro Evidence on International Patenting.* IFN Working Paper No. 934, 2012. Stockholm: Research Institute of Industrial Economics.

Marshall, C. & Rossman, G.B. (2011). *Designing Qualitative Research.* Thousand Oaks, CA: SAGE Publications.

McCracken, G. (1988). *The Long Interview.* Newbury Park, CA: SAGE Publications.

McLeish, C. & Nightingale, P. (2007). Biosecurity, Bioterrorism and the Governance of Science: The Increasing Convergence of Science and Security Policy. *Research Policy, 36*, 1635–1654.

Micara, A.G. (2012). Current Features of the European Union Regime for Export Control of Dual-Use Goods. *Journal of Common Market Studies, 50*(4), 578–593.

Molas-Gallart, J. (1997). Which Way to Go? Defence Technology and the Diversity of 'Dual-use' Technology Transfer. *Research Policy, 26,* 367–385.

Molas-Gallart, J. (1998). *Dual Use Technologies and the Different Transfer Mechanisms.* Conference Paper. Publication 55. Sussex: Complex Product Systems Innovation Centre.

Molas-Gallart, J. & Sinclair, T. (1999). From Technology Generation to Technology Transfer: The Concept and Reality of the 'Dual-Use Technology Centres'. *Technovation, 19*, 661–671.

Mowery, D.C. (2010). Military R&D and Innovation. In B. Hall & N. Rosenberg (eds), *Handbook of the Economics of Innovation* (pp. 1220–1256). Amsterdam: Elsevier.

Mowery, D.C. (2012). Defense-related R&D as a model for 'Grand Challenges' Technology Policies. *Research Policy, 41*(10), 1703–1715.

Nammo. (2011). *Annual Report*. Retrieved February 26, 2013, from http://gevir.ipapercms.dk/Nammo/2011/

Nelson, A.J. (2009). Measuring Knowledge Spillovers: What Patents, Licenses and Publications Reveal about Innovation Diffusion. *Research Policy, 38*, 994–1005.

Norwegian Industrial Property Office. (2012). *Advanced Patent Search.* Accessed between 9 May and 1 October 2012, from https://dbsearch2.patentstyret.no/AdvancedSearch.aspx?Category=Patent

Norwegian Ministry of Defence. (2006). *Forsvaret og industrien – strategiske partnere. Strategi for de næringspolitiske aspekter ved Forsvarets anskaffelser.* St.meld.[White Paper] nr 38 (2006–2007). Oslo: Forsvarsdepartementet.

Pavitt, K. (1984). Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. *Research Policy, 13,* 343–373.

Punch, K.F. (2005). *Introduction to Social Research: Quantitative and Qualitative Approaches.* London: SAGE.

Ragin, C.C. & Amoroso, L.M. (2011). *Constructing Social Research.* Thousand Oaks, CA: SAGE.

Reppy, J. (1999). Dual-Use Technology: Back to the Future? In A.R. Markusen & S.S. Costigan (eds), *Arming the Future: A Defense Industry for the 21st Century* (pp. 269–284). New York: Council on Foreign Relations Press.

Reppy, J. (2006). Managing Dual-Use Technology in an Age of Uncertainty. *The Forum, 4*(1), 1–10.

Schmoch, U. (2008). *Concept of Technology Classification for Country Comparisons: Final Report to the World Intellectual Property Organisation.* Retrieved 26 September 2012, from http://www.wipo.int/export/sites/www/ipstats/en/statistics/patents/pdf/wipo_ipc_technology.pdf

Skogen, E. (2003). Radiolinjer. *Fra Forsvarets forskningsinstitutts historie, 4*. Retrieved 28 February 2013, from http://www.ffi.no/no/Publikasjoner/Documents/FFIs-historie-nr4.pdf

Smit, W.A. (2001). Science, Technology, and the Military. In N.J. Smelser & P.B. Baltes (eds), *International Encyclopedia of the Social and Behavioral Sciences* (pp. 13698–13704). Amsterdam: Elsevier.

Smith, K. (2005). Measuring Innovation. In J. Fagerberg, D.C. Mowery & R.R. Nelson (eds), *The Oxford Handbook of Innovation* (pp. 148–177). New York: Oxford University Press.

Stowsky, J. (1992). From Spin-Off to Spin-On: Redefining the Military's Role in American Technology Development. In W. Sandholtz, M. Borrus, J. Zysman, K. Conca, J. Stowsky, S. Vogel, & S. Weber (eds), *The Highest Stakes: The Economic Foundations of the Next Security System* (pp. 114–140). New York: Oxford University Press.

Stowsky, J. (2004). Secrets to Shield or Share? New Dilemmas for Military R&D Policy in the Digital Age. *Research Policy, 33*, 257–269.

Svensgård, T. (2008). Forging Close Cooperation. *Defence & Security Technology: Showcasing Norwegian Industry Capabilities.* Annual report 51, 2008–2009. Norway Exports.

Svensgård, T. (2012, 26 March). *Status og muligheter for forsvars- og sikkerhetsindustri.* Retrieved 11 September 2012, from Oslo Military Society http://www.oslomilsamfund.no/oms_arkiv/2012/2012-03-26-Svensgård.html

Tabachnick, B.G, & Fidell, L.S. (2007). *Using Multivariate Statistics.* Boston, MA: Pearson Education.

Thompson, P. & Fox-Kean, M. (2005). Patent Citations and the Geography of Knowledge Spillovers: A Reassessment. *American Economic Review, 95*(1), 450–460.

Trajtenberg, M. (1990). A Penny for Your Quotes: Patent Citations and the Value of Innovations. *RAND Journal of Economics, 21*(1), 172–187.

Tvetbråten, K. (2011). *Forsvarsindustrien i Norge – statistikk 2010.* FFI Report 2011/02264. Kjeller: Norwegian Defence Research Establishment.

Tvetbråten, K. & Fevolden, A.M. (2011). *Forsvarindustrien i Norge – statistikk 2009.* FFI Report 2011/00608. Kjeller: Norwegian Defence Research Establishment.

Verspagen, B. & Loo, I.D. (1999). Technology Spillovers between Sectors and over Time. *Technological Forecasting and Social Change, 60*, 215–235.

Wicken, O. (1990). Modernization through Military Industry: The Creation of a 'Military-Industrial System' in Norway 1960–1975. In N.P. Gleditsch & O. Njølstad (eds), *Arms Races: Technological and Political Dynamics* (pp. 140–153). Oslo: International Peace Research Institute.

Winchester, H.P.M. & Rofe, M.W. (2010). Qualitative Research and its Place in Human Geography. In I. Hay (ed.), *Qualitative Research Methods in Human Geography* (pp. 1–25). Ontario: Oxford University Press.

World Intellectual Property Organisation. (2011, August). *IPC – Technology Concordance Table*. Retrieved 26 September 2012, from http://www.wipo.int/ipstats/en/statistics/technology_concordance.html

Yin, R.K. (2009). *Case Study Research: Design and Methods.* Thousand Oaks, CA: SAGE.

# Appendices

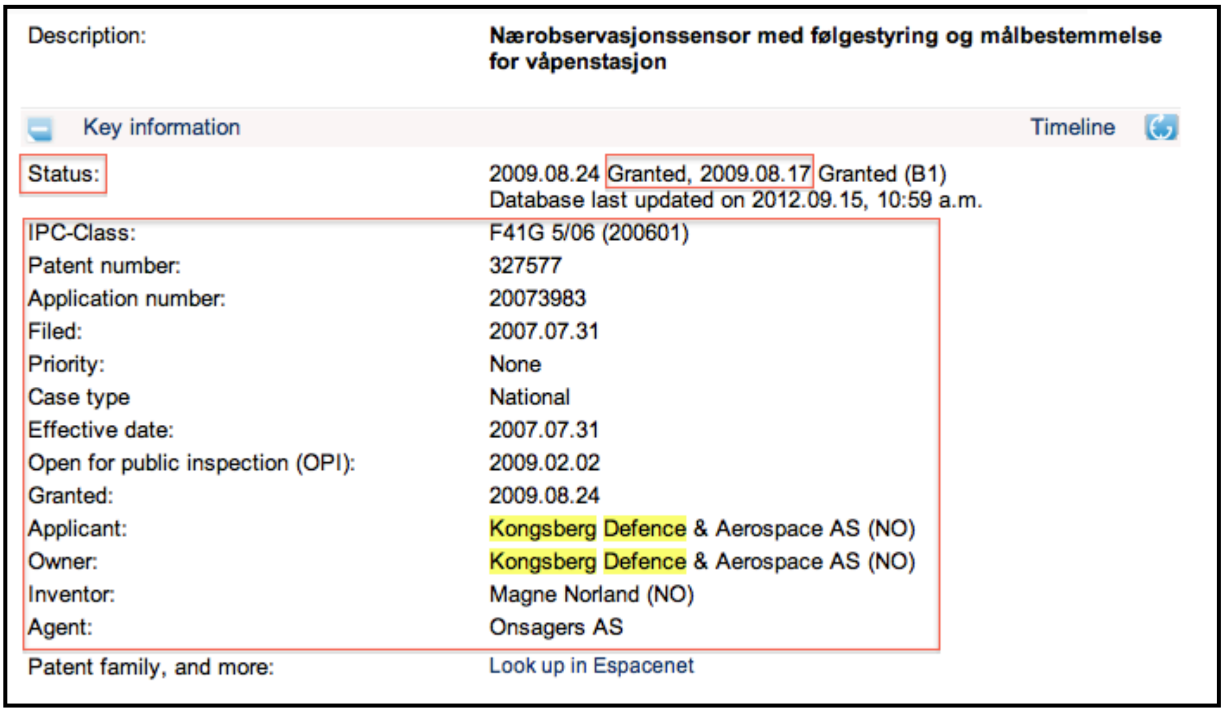
# Appendix 1 – Defence Firms

**Table 1** Firms in the Norwegian defence industry, as of mid-May 2012 – 100 firms.

| | | |
|---|---|---|
| | Volvo Aero Norge | Nacre AS |
| TINEX AS | Nera ASA | Nammo Raufoss AS |
| NFM Group AS | Nordic Corporation AS | ROFI Industrier AS |
| Kongsberg Defense and Aerospace AS | Thales Norway AS | Bandak AS |
| Kitron AS | T&G Elektro AS | Teleplan Globe |
| Camp Supply International Norway | Aktiv styring AS | Bedriftsystemer AS |
| ComPower AS | Electronicon AS | Equipnor AS |
| Flextronics International Norway AS | Fred. Olsen Fly og Luftmateriell A/S | IFS Norge AS |
| Jotne EPM Technology | Kongsberg Devotek | Kongsberg Maritime AS |
| Kongsberg Mikroelektronikk | Lenco Software | Nordic Power Systems |
| TAM AS | Umoe Mandal as | Vibratec Akustikkprodukter |
| Triad AS | Nodin Aviation AS | Vmetro ASA |
| Saab Technologies Norway AS | Nordic Shelter AS | Vinghøg AS |
| FotoPhono AS | Janusfabrikken AS | Oskar Pedersen AS |
| Gudbrandsdal Industrier AS | Comrod AS | Seaproof Solutions |
| JOTRON AS | Eidsvoll Electronics AS | Ibruk as |
| Applica Consulting AS | Bergen Group | Bertel O. Steen Industries AS |

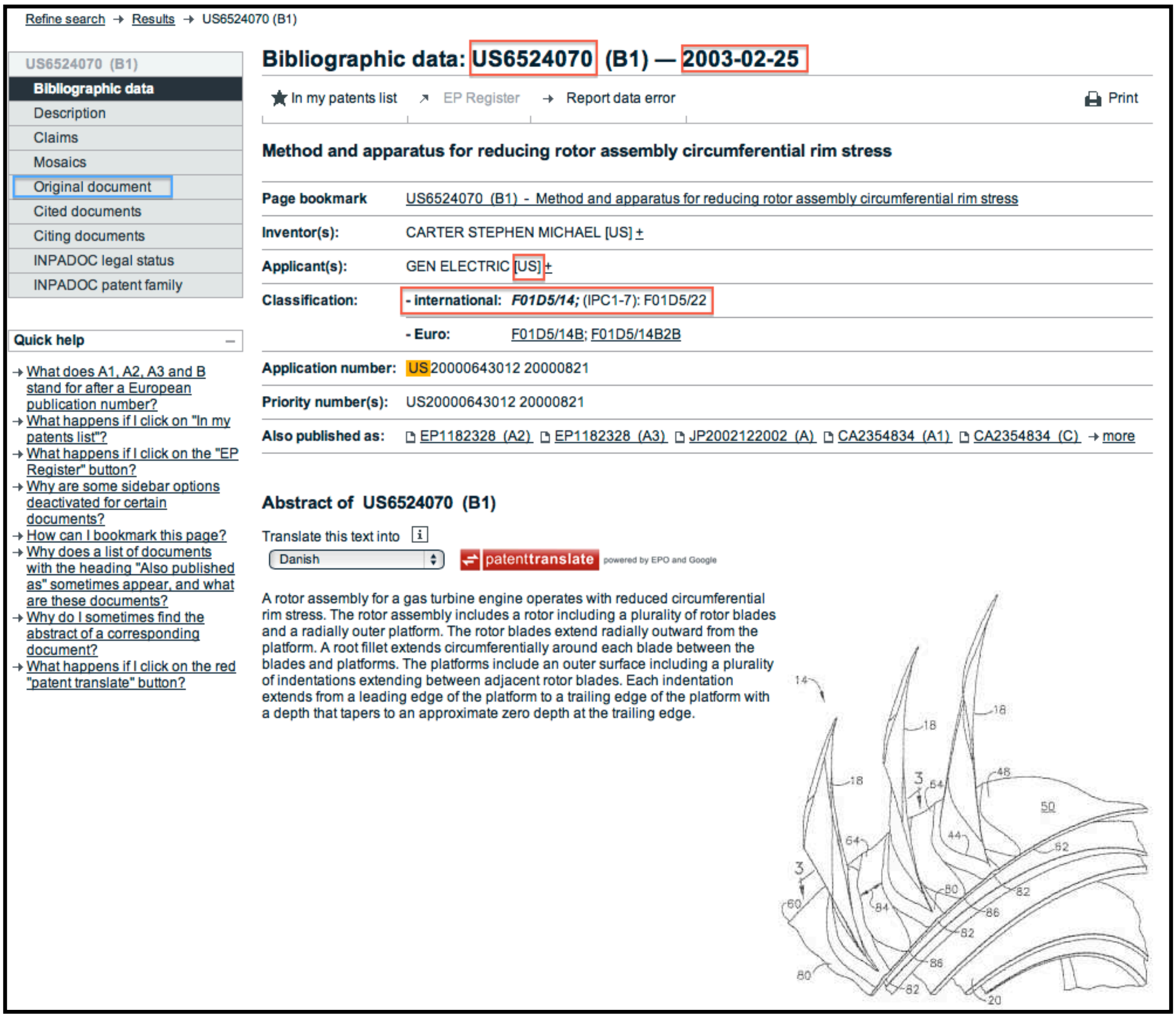
| | | |
|---|---|---|
| Chemring Nobel AS | Corena Norge AS | Det Norske Veritas AS |
| Drytech AS | Gylling Teknikk AS | Intech AS |
| International Business Machines (IBM) Norge AS | Kongsberg Seatex AS | Lena Metall AS |
| Norwegian Defence Logistic Organisation / Air Depot Kjeller) | Marshall SV | Natech NSV AS |
| NDS – Nordic Defence Supply AS | NorLense AS | Teleplan Consulting |
| Norautron AS | Norsk Scania | Obsima Technology AS |
| Propartner Defence AS | Rodhe og Schwarz AS | PMC Servi AS |
| Saab International Norge AS | Safety & Security Service AS | Scanmatic AS |
| Trelleborg Offshore Norway AS – Defence | Tronrud Engineering AS | Ullandhaug Invest AS |
| VBK Nordic | Viking Life-saving Equipment | Dolphin Interconnect Solutions AS |
| Eidel | Elop-DolphiScan AS | Falck Nutec AS |
| Geodata AS | Gunnar Mjell Consulting | Industriell Dokumentasjon AS |
| Keytos | Merlin Design | MPNOR AS |
| Saab Microwave Systems AS | SiMiCon AS | Simrad Optronics |
| SINTEF-Gruppen | Techni | Terramar AS |
| UMS Norway | Sensonor AS | Simpro AS |
| Kongsberg Defense Communication | | |

# Appendix 2 – Patent and Citation Search



| | |
|---|---|
| Description: | **Nærobservasjonssensor med følgestyring og målbestemmelse for våpenstasjon** |
| Key information | Timeline |
| Status: | 2009.08.24 Granted, 2009.08.17 Granted (B1)<br>Database last updated on 2012.09.15, 10:59 a.m. |
| IPC-Class: | F41G 5/06 (200601) |
| Patent number: | 327577 |
| Application number: | 20073983 |
| Filed: | 2007.07.31 |
| Priority: | None |
| Case type | National |
| Effective date: | 2007.07.31 |
| Open for public inspection (OPI): | 2009.02.02 |
| Granted: | 2009.08.24 |
| Applicant: | Kongsberg Defence & Aerospace AS (NO) |
| Owner: | Kongsberg Defence & Aerospace AS (NO) |
| Inventor: | Magne Norland (NO) |
| Agent: | Onsagers AS |
| Patent family, and more: | Look up in Espacenet |

**Figure 2.1** Example of a patent search at the Norwegian Industrial Property Office. Note: everything marked within the red border is noted as patent information in a excel sheet. Source: Norwegian Industrial Property Office (2012).



Refine search → Results → US6524070 (B1)

US6524070 (B1)

Bibliographic data
Description
Claims
Mosaics
Original document
Cited documents
Citing documents
INPADOC legal status
INPADOC patent family

Quick help

→ What does A1, A2, A3 and B stand for after a European publication number?
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→ Why do I sometimes find the abstract of a corresponding document?
→ What happens if I click on the red "patent translate" button?

## Bibliographic data: US6524070 (B1) — 2003-02-25

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**Method and apparatus for reducing rotor assembly circumferential rim stress**

| | |
|---|---|
| **Page bookmark** | US6524070 (B1) - Method and apparatus for reducing rotor assembly circumferential rim stress |
| **Inventor(s):** | CARTER STEPHEN MICHAEL [US] + |
| **Applicant(s):** | GEN ELECTRIC [US] + |
| **Classification:** | **- international:** ***F01D5/14;*** (IPC1-7): F01D5/22 |
| | **- Euro:** F01D5/14B; F01D5/14B2B |
| **Application number:** | US20000643012 20000821 |
| **Priority number(s):** | US20000643012 20000821 |
| **Also published as:** | EP1182328 (A2) EP1182328 (A3) JP2002122002 (A) CA2354834 (A1) CA2354834 (C) → more |

**Abstract of US6524070 (B1)**

Translate this text into
Danish
patenttranslate powered by EPO and Google

A rotor assembly for a gas turbine engine operates with reduced circumferential rim stress. The rotor assembly includes a rotor including a plurality of rotor blades and a radially outer platform. The rotor blades extend radially outward from the platform. A root fillet extends circumferentially around each blade between the blades and platforms. The platforms include an outer surface including a plurality of indentations extending between adjacent rotor blades. Each indentation extends from a leading edge of the platform to a trailing edge of the platform with a depth that tapers to an approximate zero depth at the trailing edge.

**Figure 2.2** Example of a patent search at the European Patent Office, worldwide search. Note: everything marked within the red border is noted as patent information in a excel sheet. In addition, clicking on the tab marked in blue leads one further to an original scanned document describing the invention – hence, giving more information to set the main technology as well as decide whether it is for civilian use. Source: Espacenet (2012).

# Appendix 3 – Technology Concordance Table

**Table 3.1** International Patent Classification codes (IPC), by fields and classes. Note: Number 30 is added to separate weapons and munitions from category 29. Source: WIPO IPC Technology Concordance Table from Schmoch (2008, p. 10) brought up to date from WIPO (2011).

| | | Class | IPC Code |
|---|---|---|---|
| I | **Electrical engineering** | | |
| 1 | | Electrical machinery, apparatus, energy | F21#, H01B, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01R, H01T, H02#, H05B, H05C, H05F, H99Z |
| 2 | | Audio-visual technology | G09F, G09G, G11B, H04N, H05K, H04R |
| 3 | | Telecommunications | G08C, H01P, H01Q, H04B, H04H, H04J, H04K, H04M, H04N, H04Q |
| 4 | | Digital communication | H04L, H04W |
| 5 | | Basic communication processes | H03# |
| 6 | | Computer technology | G06C, G06D, G06E, G06F, G06G, G06J, G06K, G06M, G06N, G06T, G10L, G11C |
| 7 | | IT methods for management | G06Q |
| 8 | | Semiconductors | H01L |
| II | **Instruments** | | |
| 9 | | Optics | G02B, G02C, G02F, G03B, G03C, G03D, G03F, G03G, G03H, H01S |
| 10 | | Measurement | G01B, G01C, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G01Q, G01R, G01S, G01V, G01W, G04B, G04C, G04D, G04F, G04G, G12B,G99Z |
| 11 | | Analysis of biological materials | G01N |
| 12 | | Control | G05B, G05D, G05F, G07#, G08B, G08G, G09B, G09C, G09D |
| 13 | | Medical technology | A61B, A61C, A61D, A61F, A61G, A61H, A61J, A61L, A61M, A61N, H05G |
| III | **Chemistry** | | |
| 14 | | Organic fine chemistry | C07B, C07C, C07D, C07F, C07H, C07J, C40B, A61K, A61Q |
| 15 | | Biotechnology | C07G, C07K, C12M, C12N, C12P, C12Q, C12R, C12S |
| 16 | | Pharmaceuticals | A61K |
| 17 | | Macromolecular chemistry, polymers | C08B, C08C, C08F, C08G, C08H, C08K, C08L |
| 18 | | Food chemistry | A01H, A21D, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, C12C, C12F, C12G, C12H, C12J, C13D, C13F, C13J, C13K |
| 19 | | Basic materials chemistry | A01N, A01P, C05#, C06#, C09B, C09C, C09F, C09G, C09H, C09K, C09D, C09J, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C10N, C11B, C11C, C11D, C99Z |
| 20 | | Materials, metallurgy | C01#, C03C, C04#, C21#, C22#, B22# |
| 21 | | Surface technology, coating | B05C, B05D, B32#, C23#, C25#, C30# |
| 22 | | Micro-structure and nano-technology | B81#, B82# |
| 23 | | Chemical engineering | B01B, B01D, B01F, B01J, B01L, B02C, B03#, B04#, B05B, B06B, B07#, B08#, D06B, D06C, D06L, F25J, F26#, C14C, H05H |
| 24 | | Environmental technology | A62D, B01D, B09#, B65F, C02#, F01N, F23G, F23J, G01T, E01F, A62C |
| IV | **Mechanical engineering** | | |
| 25 | | Handling | B25J, B65B, B65C, B65D, B65G, B65H, B66#, B67# |
| 26 | | Machine tools | B21#, B23#, B24#, B26D, B26F, B27#, B30#, B25B, B25C, B25D, B25F, B25G, B25H, B26B |
| 27 | | Engines, pumps, turbines | F01B, F01C, F01D, F01K, F01L, F01M, F01P, F02#, F03#, F04#, F23R, G21#, F99Z |
| 28 | | Textile and paper machines | A41H, A43D, A46D, C14B, D01#, D02#, D03#, D04B, D04C, D04G, D04H, D05#, D06G, D06H, D06J, D06M, D06P, D06Q, D99Z, B31#, D21#, B41# |
| 29 | | Other special machines | A01B, A01C, A01D, A01F, A01G, A01J, A01K, A01L, A01M, A21B, A21C, A22#, A23N, A23P, B02B, C12L, C13C, C13G, C13H, B28#, B29#, C03B, C08J, B99Z |
| 30 | | Weapons and munitions | F41#, F42# |

| | | | |
|---|---|---|---|
| 31 | | Thermal processes and apparatus | F22#, F23B, F23C, F23D, F23H, F23K, F23L, F23M, F23N, F23Q, F24#, F25B, F25C, F27#, F28# |
| 32 | | Mechanical elements | F15#, F16#, F17#, G05G |
| 33 | | Transport | B60#, B61#, B62#, B63B, B63C, B63G, B63H, B63J, B64# |
| **V** | **Other fields** | | |
| 34 | | Furniture, games | A47#, A63# |
| 35 | | Other consumer goods | A24#, A41B, A41C, A41D, A41F, A41G, A42#, A43B, A43C, A44#, A45#, A46B, A62B, B42#, B43#, D04D, D07#, G10B, G10C, G10D, G10F, G10G, G10H, G10K, B44#, B68#, D06F, D06N, F25D, A99Z |
| 36 | | Civil engineering | E02#, E01B, E01C, E01D, E01F, E01H, E03#, E04#, E05#, E06#, E21#, E99Z |

# Appendix 4 – Choice of Respondents

**Most-cited firms**

| **Defence firm** | **Mean of civilian citations received (n=392)** | **Standard deviation** |
|---|---|---|
| Nacre AS | 16.20 | 25.626 |
| Nera | 8.33 | 6.802 |
| Sensonor | 4.00 | 5.657 |
| Kongsberg Defence & Aerospace | 3.81 | 6.372 |
| Nammo | 1.39 | 3.328 |
| Comrod | 0.67 | 1.155 |

**Table 4.1** Distribution of the most-cited defence firms, reported by mean and s.d.

**Most-cited technologies**

| **Technology** | **Mean of civilian citations received** | **Standard deviation** |
|---|---|---|
| Audio-visual technology | 16.20 | 25.626 |
| Digital communication | 8.50 | 10.607 |
| Engines, pumps and turbines | 7.64 | 7.685 |
| Basic communication processes | 6 | 5.831 |
| Materials, metallurgy | 5.50 | 7.778 |
| Measurement | 5.18 | 7.613 |
| Telecommunications | 2.29 | 4.786 |
| Machine tools | 0.63 | 1.408 |

**Table 4.2** Distribution of most- cited civilian technological fields, reported by mean and s.d.

# Appendix 5 – Interview Guide

## Interview Guide

*'FIRM'*

### Introduction

- Fully informed consent?
- Your position and role at *'FIRM'?*
- Research questions and objectives of my thesis
- Findings from a patent analysis

### Dual-use technology

- What do you know about defence–civilian spillover of dual-use technology?
- In your opinion, to what extent do civilian industries benefit from technologies developed by the Norwegian defence industry?
- Can you give have any examples?

### Factors of dual-use technology

#### External cooperation

- Do you recollect any projects where the development of some technologies was done in collaboration with other firms that were interested in adapting some technologies for commercial needs?
    - Cooperation with clients?
        - What type of clients? Who are they?
    - Cooperation with civilian enterprises?
        - Are these clients or suppliers?
    - Other types of collaborations?

- Have you experienced or do you feel that the industry-specific procurement policies, governmental regulations and rules inhibit cooperation or contact with civilian markets?

#### Technological breadth

- How do you consider the innovative effect of integrating diverse technologies, rooted in different knowledge bases, in order to develop new products and processes?
    - Do these tend to develop into dual-use technologies?

- Do you experience that the spin-in of technologies from civilian industries contributes to tighten the industrial linkages between *'FIRM'* and civilian industries?
    - Do you treat such spin-in technologies as COTS or do you create new applications based on those technologies?
        - Have any of these spun off to civilian applications?

- What is *'FIRM'* opinion on sharing information on technological developments? How does the enterprise stand when it comes to using strategic factors such as the IPR regime versus secrecy?
    - Could the potential civilian interest of technologies outweigh the disadvantages of not keeping things secret?

**Innovative capabilities**

- Do you consider company capabilities, such as R&D investments and labour stock, important for innovating and producing technologies?
    - Does the publicly financed R&D affect the firm's own investments in R&D?
    - How do you consider *'FIRM's'* ability to commercialise product and process technologies?

- Of the examples you have mentioned, is there a tendency for technologies to result in dual-use application at an early stage of development or at a later, more developed stage?
    - How do you assess the interest from the global market?

- What type of technologies do civilian firms tend to be interested in?
    - In which types of technologies are these integrated or used?

**Civilian orientation**

- Would you say that *"FIRM"* is focused towards civilian markets?
    - Have you experienced any benefits of such orientation compared to a more defence orientation?
- How important is it to "*FIRM"* to sell products and services to purely military customers?
    - Do the increased revenues from sales to such customers define your range of products?
    - Do such revenues impact on whom you choose to cooperate with?

## Additional

- Are there any policy changes that could enhance civilian usage of defence industrial technologies?
- Do you know, or could you recommend, specific branches of the enterprise, or persons with knowledge about the questions asked?
- Is there anything else that you feel should have been brought up this conversation?