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Abstract

The paper investigates the trade-off between innovation and defence industrial policy. It presents an agent-based simulation model calibrated for the Norwegian defence industry that compares different policy scenarios and examines the effects of a pending EU market liberalization process. The paper points to two main results. (1) It finds that a pure scenario where national authorities focus on, and provide support exclusively for, either a) international competitiveness or b) national defence and security objectives, is more Pareto efficient than a corresponding mixed strategy where policy makers simultaneously pursue both international competitiveness and defence and security objectives. (2) Under the conditions of the new EU liberalization regime, it finds that a stronger and more visible trade-off will emerge between international competitiveness and national defence and security objectives. Policy makers will have to choose which to prioritise, and set a clear agenda focusing on one of the two objectives.

1. Introduction

The European Union's Defence and Security Procurement Directive (2009/81/EC) will during 2011 and 2012 be transposed into national law by EU (European Union) and EFTA (European Free Trade Association) Member States. The intention behind the Directive is to ensure free trade of defence and security equipment within the European Economic Area (EEC) and thereby increase competition, reduce duplication, lower prices and eventually strengthen the international competitiveness of the European defence sector. Although the actual impact of the Directive is still uncertain, it is likely that many Member States will find it more difficult to maintain protectionist policies such as national favouritism and offset (counter-trade) requirements. Nevertheless, the Directive might not affect each member country in the same way or to the same extent. Some authors have already begun to speculate that the Directive will impact member countries differently according to the size of their national defence markets and the strengths of their defence industrial base [1]. One concern, in this regard, is that a higher degree of market liberalization in the European defence market might lead to rationalization of production and lower costs of defence equipment for the EU as a whole, but that smaller Member States, such as Norway, might find that these benefits are offset by the impediments that the Directive creates with respect to achieving other important policy goals.

Norway has traditionally sought to foster a strong domestic defence industry because it considered this sector vital for reaching two distinct types of policy objectives. On the one hand, national authorities have provided innovation policy support to the domestic defence industry because they believed that defence companies could foster economic growth and international competitiveness by introducing technologically advanced innovations and generating strong positive spillover effects to related domestic industries. On the other hand, public authorities have also supported the domestic defence industry through traditional defence industrial policies because they believed that defence companies could provide the armed forces with access to high-end technological expertise and ensure that the country had a steady supply of spare parts and munitions in times of a national crisis. The Norwegian Government has pursued these two policy objectives through two different types of policy instruments: (1) innovation policies that encourage the introduction of *specialized products and components* based on high-end technological expertise; and (2) defence industrial policies that encourage the introduction of *complex weapon*

systems and platforms based on integration of a broad base of technologies. The former has significantly sustained the economic performance and international competitiveness of so-called *specialized supplier* companies [2], whereas the latter has fostered technological and military capabilities of the largest firms in the Norwegian defence sector, which are those that can play the role of *system integrators*.

This policy background leads to formulate some important questions. How do these two distinct policy goals affect one another, is there a trade-off and contrast between them? Relatedly, how will the introduction of the new EU directive affect these two policy objectives and the relationship, or trade-off, between them? Motivated by these two research questions, the present article intends to:

    i.   Investigate the trade-off and contrasting effects of two different policy objectives in the defence industry: strengthening military capabilities through defence industrial policy *versus* fostering the companies' international competitiveness through innovation policy.

    ii.   Examine whether and the extent to which a greater degree of market liberalization in the future, as a consequence of the implementation of the new EU Directive, will affect this trade-off.

To investigate these research issues, the article will set up and analyse an agent-based model of the defence industry, which will simulate the dynamics of the Norwegian defence industry under different policy scenarios. The model is based on and extends the so-called SKIN model (*Simulating Knowledge Dynamics in Innovation Networks*), which provides an analysis of private firms' interactions and knowledge dynamics in high-tech industries, developed in a number of recent articles by Gilbert et alia, Pyka et alia and Ahrweiller et alia [3,4,5]. Our approach is rooted in these recent models, but extends them further by applying it to the relationship between international competitiveness and military capabilities within a context of increasing market liberalization in the defence sector.

The simulation analysis carried out in this article looks at the effect of three different policy strategies – "*pure*" innovation policy,' "*pure*" defence industrial policy' & "*mixed*" innovation and defence industrial policy. Each of these is analysed under two different institutional regimes – *before* and *after* the introduction of the new EU Directive. The simulation analysis points out three main results: (1) There is a clear trade-off between *pure* innovation and *pure* defence industrial policies – pursing innovation policies will improve international competitiveness of the firms at the expense of their military capabilities,

and *vice versa*. (2) Pursuing a *mixed* strategy – of combining innovation and defence industrial policy support – strengthens the firms' military capabilities slightly more than *pure* defence industrial policies, but at the cost of a severe decline in their international competitiveness. (3) These trade-offs are maintained even after the introduction of the new EU Directive, but the international competitiveness of the firms increases significantly for all policy scenarios. Based on these findings, the article points out that national authorities should consider abandoning "mixed" policy strategies and instead pursue "pure" policy strategies that focus on only one of the objectives. It also points out that increasing liberalization might constitute more of an opportunity than a threat for the Norwegian defence industry, but that national authorities need to consider carefully what their most important policy goal is – strengthening the military capabilities of their firms or their international competitiveness.

Although the main topic of the paper is the trade-off between innovation and defence industrial policies, the insights gained through the analysis might be relevant for other sectors of the economy as well. We believe that the findings in this paper can be especially useful for understanding industries where there is a dynamic, complex and conflicting relationship between economically efficient production and important social externalities. In food production, for instance, some farming methods help maintain the cultural landscape and contribute to tourism and sustainable development, but they are not necessarily the most efficient; and in energy production, some means of energy production are less efficient, but they are more reliable and contribute to a higher level of energy security. We believe that this article may provide insights that can be valid for these and other sectors of the economy.

The paper is organized in the following way. Section 2 provides background information on the Norwegian defence industry and policy regimes and points out some facts that the model seeks to reproduce; section 3 presents the model; section 4 defines the firm level and industry-level variables used in the simulation analysis; section 5 presents the main outcomes of the model and discusses some alternative policy scenarios; and section 6 concludes by summarizing the key results and implications of the work.

2. Background: innovation and defence industrial policy in Norway

The Norwegian defence industry consists of a population of around 120 fairly heterogeneous companies [6]. A limited number of large multi-product and multi-competence companies are the strongest players in the defence market and can be described as *systems integrators* in sense that they deliver complete weapon systems or platforms. The rest of the companies in the Norwegian market are instead small or medium-sized (or larger civilian companies with a small military business on the side), and can be described as *specialized suppliers*, in the sense that they produce either specialized components (e.g. for weapon systems) or "simple," stand-alone military equipment. Although the Norwegian defence industry is small compared to the defence industries in other European countries, it has a wide span of technological competencies and a broad portfolio of products – producing everything from tactical communications and crypto solution to ammunitions and military explosives, from tents and protective suits to components for aircrafts, vehicles, vessels and submarines. The Norwegian defence contractors are also as a whole very export intensive compared to most other defence firms in Europe [7]. Although, there are great variations from company to company, Norwegian defence firms receive on average about half of their revenues from foreign clients. Both this breadth of competence and the high export intensity are not only a result of market dynamics, but to a large extent also the consequence of policies that have been in place since the early post WW2 period.

Norwegian policies toward its domestic defence industry have been greatly influenced by its post-WW2 reconstruction efforts and the country's ratification of the North Atlantic Treaty [8] (the founding document of the NATO alliance). Unlike its neighbour Sweden – which pursued a policy of neutrality and needed to be self-sufficient in terms of defence equipment – Norway could through its membership in NATO depend on other member countries for access to defence material. Nevertheless, the Norwegian Government wanted to ensure that its armed forces had a secure supply of spare parts and munitions and began in the first post war decades to support the build-up of a Norwegian defence industry that could support its armed forces with critical capabilities and components. The Norwegian Government found another reason to support its domestic defence industry in the 1970s. Norway was devastated during WW2 and began in the early

post war decades an ambitious program of reconstruction. The Norwegian Government believed initially that supporting the development of a domestic defence industry could take resources away from its reconstruction efforts, but changed its mind during the 1970s when it realized that production of sophisticated military products could help modernized its industry and that exporting defence equipment could provide the country with much needed foreign currency. These two policy goals – strengthening military capabilities and fostering international competitiveness – were typically pursued by two different types of policies, *defence industrial policy* and *innovation policy* respectively, and have since the early post war years served as beacons for the Norwegian policy development *vis-à-vis* its domestic defence industry.

Two of the most important institutions shaping the innovation and defence industrial policy landscape in Norway today are *Innovation Norway* (IN) and the Norwegian *Ministry of Defence* (MoD). Both IN and the MoD have been tasked by the Government with promoting a strong and viable defence industry in Norway, but for different reasons and through different means. IN has been given the responsibility for the innovation policy and support defence companies that can stimulate economic growth by generating positive spill-over effects and opening up new export markets. It supports the defence industry through a wide variety of innovation and internationalization-related support programs, directed primarily towards small and medium sized (specialized suppliers) companies. The Norwegian MoD, on the other hand, has been given the responsibility for the defence industrial policy and support defence companies that can provide the armed forces with access to the high-end technological expertise that it needs when it acquires new military equipment and ensure that it has a steady supply of spare parts and munitions in times of a national crisis. It supports the defence industry primarily through acquisition-related R&D support programs and export-stimulating offset agreements, which often benefit companies with a broad technological competency base.

Although both IN and the Norwegian MoD are tasked with promoting a strong and viable defence industry, it is an open question whether their policy goals are compatible or whether their policy instruments support one another. The companies that the Norwegian MoD supports are those that have capabilities that are useful in a military context, while the companies that IN promotes are those that have specific expertise that is useful in terms of e.g. foreign commercialization and export activities. These two spheres are often in sharp contrast with each other. However, few studies have discussed the possible contrast between innovation and defence industrial policy. Martin, Brauer and Dunne have investigated the economic effects of offset (counter-trade)

agreements and found that they tend to increase the cost of military equipment, while promoting economic growth only marginally [9,10]. Apostolakis has found that trade-barriers on defence equipment (Buy American Act) can have detrimental effects on the cost and quality of defence equipment [11]. Nevertheless, none of these previous studies have systematically compared the costs and benefits of focusing on military capability building versus fostering innovation and the international competitiveness of defence companies.

It is still an open question to what extent EU and EFTA Member States will still be able to make use of defence industrial policies after the European Union's Defence and Security Procurement Directive (2009/81/EC) will have been transposed into national law. The intention behind the Directive is to ensure free trade of defence and security equipment within the European Economic Area, and it is likely that many Member States will find it more difficult to maintain protectionist policies such as national favouritism and offset (counter-trade) requirements. Nevertheless, the Directive opens up for the use of many other policy instruments, such as R&D support to domestic companies (up to a certain technological maturity level) and direct purchase without competition from national industries if their products have been developed as part of an international joint ventures involving a considerable amount of R&D [12]. For the Norwegian defence contractors this implies that they might find it somewhat easier to sell their products to other European countries, but at the same time they will face increased competition both in foreign and domestic markets. For the Norwegian Government, this implies that it can, at least to some extent, continue to support its domestic industry, although national defence authorities will have to rethink the rationale and appropriate mix of the policy objectives they pursue and the policy instruments they adopt.

3. The model

Agent-based models and simulations (ABMS) provide a framework to analyse a set of heterogeneous agents and the interactions among them [13,14,15]. A specific model of our interest is the so-called SKIN model (*Simulating Knowledge Dynamics in Innovation Networks*), introduced in a number of recent papers by Gilbert et alia, Pyka et alia and Ahrweiller et alia [16,17,18,19]. This is an agent-based model that provides an accurate analysis of private firms' interactions and knowledge dynamics in high-tech (or knowledge intensive) industries. Our paper is rooted in this recent model and extends it further by applying it to the study of the defence sector. While the main description of the model follows the main basic pillars of the SKIN approach, our model departs from it in some important ways. Figure 1 presents a diagram describing the behaviour of agents (private firms) and their market interactions within any given period t.

3.1   Defence firms

Defence firms (business companies producing defence material, equipment and products) are the micro agents in the model. Agents differ from each other in two main respects (*firm heterogeneity*). First, they have different initial endowments of financial capital, which they use both for their productive and innovative activities. Large firms co-exist with SMEs in the defence market. Secondly, they differ in terms of their knowledge base, i.e. the pool of scientific and technological competencies and skills that the company employs in its innovative activities. The model represents the firm's knowledge base as a set of units of knowledge. Each unit is a vector composed of three elements (or triple):

- The *capability* (C), which defines a domain or area within the defence industry (e.g. weapon production). It is represented in the model as a randomly chosen integer between 1 and 1000.
- The *ability* (A), defining a specific ability or skill that the firm possesses in this C domain (e.g aerodynamic design technologies for platforms and weapons). It is a randomly chosen integer between 1 and 10.
- The *expertise* (E), which indicates the level of expertise that the firm has in using the ability A. This is also represented as a randomly chosen number between 1 (lowest) and 10 (highest).

Figure 1: Model flowchart
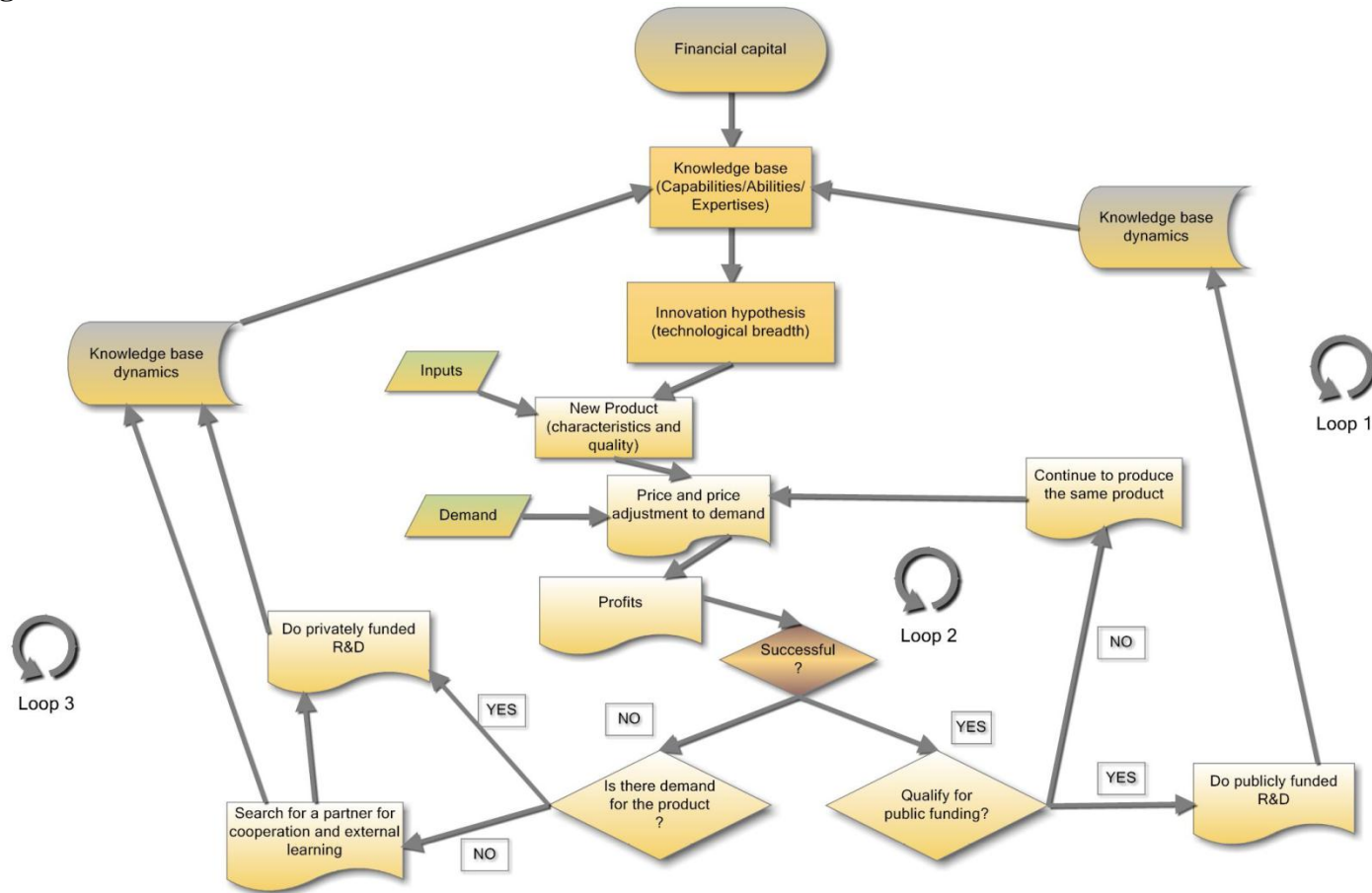
Legend:
Loop 1: Successful firms that qualify for public funding
Loop 2: Successful firms that do not qualify for public funding
Loop 3: Unsuccessful firms doing privately funded R&D and cooperation

Defence firms compete in a highly innovative and technologically sophisticated environment (see section 2). Our model assumes that all firms in the market actively use their knowledge base in the attempt to create new products and processes. Innovative activities are represented in the SKIN model in such a way that, at any period t, each company formulates an *innovation hypothesis*, i.e. an idea or a plan for developing a new product or process. The model represents this innovation hypothesis (IH) as a subset of the firm's knowledge base, i.e. the enterprise focuses on a specific subset of its technological competence (capabilities, abilities, expertise) that it finds particularly promising and worth developing further. The subset of expertise (E_i) used in the innovation hypothesis are assumed to increase by one unit in the period, whereas those that are not used decrease by one unit (*learning by doing* and *forgetting* mechanisms).

3.2 The defence market

In any period t, each enterprise uses its innovation hypothesis to try to develop a new product. The outcomes of the innovative process are subject to a high degree of uncertainty and introduce an important stochastic element in the model. The new product is characterized as an index number that depends on the number of capabilities and abilities entailed in the innovation hypothesis according to the function:

$$P = (\sum C_i \cdot A_i) \bmod N \tag{1}$$

where N is the maximum number of different products. The product is therefore characterized by the *breadth* of the innovation hypothesis, i.e. the number of different capabilities and abilities that the firm masters and it is able to combine in the development of the new artefact. By contrast, the quality of the product depends on the *depth* of the innovation hypothesis, i.e. it is a function of the enterprise's specific abilities and expertise. Specifically, product quality is defined as an index number obtained by multiplying the abilities and expertise levels for each of the vectors composing the innovation hypothesis and then normalizing the result. In other words, the key characteristic and value added of a new product does not depend on how broad the firm's technological competence is, but rather how deep and specialized the company is in a specific sub-set or market niche. As explained below, this trade-off between competence breadth *versus* depth is an important characteristic driving the model's outcomes.

In order to produce the new product, the firm searches for inputs (e.g. capital equipment) in the market. The type of input it needs depends on the characteristics of the product it wants to develop (P), and it eventually purchases the one with the lowest price and, *ceteris pari-*

bus, the highest quality. If the enterprise does not find any input in the market at a price it can afford, it will not enter the production process. Once the product is ready for market commercialization, the firm sets its price by applying a mark-up (profit margin) over the total costs. Depending on the market demand available for this product, an adjustment mechanism tends to increase (decrease) its price over time if the demand level is high (low). More specifically, the model assumes that demand patterns differ for different segments of the defence industry. On the one hand, intermediate products are sold to other firms within the defence sector and their price is subject to the adjustment mechanism noted above. On the other hand, new products that are destined to the end users are always absorbed by the market. This assumption is in line with the fact that, in the defence industry, public procurement assumes a pivotal role, i.e. defence authorities typically purchase a substantial amount of new (or existing) defence products and material from domestic firms in order to secure military capabilities and so achieve national defence strategic objectives.

Given these market interactions and outcomes, at any period *t* the firm achieves a certain level of profit – which is largely dependent on the characteristics and quality of the new product it sells.

We further assume that if the enterprise's profits are large enough to cover sunk export costs (i.e. above a given profit threshold), then the enterprise is able to start the commercialization of its product also to foreign markets. This is in line with the key idea of the recent literature on firm heterogeneity and international trade [20,21], according to which only the most successful and productive enterprises within each sector are able to pay sunk export costs and overcome trade barriers in international markets, whereas most other companies will only produce for the domestic market.

3.3   Performance adjustment and feedback loops

After having produced and commercialized its product, the firm looks at its current market performance (i.e. the profits it has realized at time *t*), and decides whether this is satisfactory or not, and how it can be improved in the future. The model's parameter *success threshold* (defined in further details in section 4) indicates the profit level that marks the distinction between successful *versus* unsuccessful performance. This parameter is exogenously set at a given level for all firms in the market. For simplicity, we start by assuming that this success threshold corresponds to the mean profit level in the industry: enterprises whose profits are above (below) the industry-level mean will be satisfied (not satisfied) with their current performance. There are two ways in which an enterprise can improve its performance over time.

One can only be pursued by unsuccessful performers, whereas the other is followed by successful innovators.

New privately-funded R&D projects and cooperation: If a firm is not satisfied with the profits it has realized, it will try to improve its performance by starting to search in a new direction [22]. An enterprise can apply two different search strategies to adjust its performance. (1) If its current product was sold in the market but the demand level was not sufficient to realize a satisfactory profit level, the company will undertake a new R&D project funded through its own internal resources (financial capital). The new R&D project will aim at improving one of the abilities (A) in its innovation hypothesis – or, put it differently, to achieve a better specialization and technological sophistication in the technological space on which it is currently focusing (i.e. an increased technological *depth*, given its current *breadth*).

(2) By contrast, if the firm's current product did not meet any demand in the market (hence leading to negative profits), this gives a clear indication that the firm's current innovation hypothesis is not well suited to the user requirements, and that it must be adjusted. The enterprise can do this by searching for an external partner for cooperation. The firm will first search among its previous partners, then its suppliers and users, by looking at the capability sets they possess as indicated by their respective innovation hypotheses and market product characteristics. When a firm finds a collaboration partner, it can add the partner's innovation hypothesis triples to its own, thus achieving a broadening up of its capability set and knowledge base. Put it differently, cooperation enables the exchange of knowledge among different agents, and this is likely to improve the performance of these by augmenting their respective knowledge bases and technological competencies. All in all, the two strategies pursued by unsuccessful performers – privately-funded R&D and cooperation – introduce in the model a catch up mechanism, since firms lagging behind the technological frontier may improve their technological position and adjust their market performance by means of such R&D and imitation strategies.

Public funding and policy objectives: If a firm is satisfied with the profits it has realized, it may decide to apply for public funding for improving its product further (publicly-funded incremental innovation). Public defence authorities typically finance a substantial amount of domestic R&D activities through public procurement, as noted in section 2. We assume that this public funding is granted to the applicant according to two different criteria: (1) The quality of the firm's product has to be above a given product quality threshold; (2) The firm's technological and competence breadth (i.e. the number of capa-

bilities C in its innovation hypothesis) has to be above a given competence breadth threshold. The intuition behind this public funding allocation mechanism is in line with the practice that public defence authorities typically follow. Put it simply, when policy-makers evaluate the possibility to finance a company to develop a new product, they look at two different aspects:

(1) The quality of its current product, which gives them an indication of the likelihood that the firm will be able to produce a successful incremental innovation of it in the future. This is the key dimension that policy-makers want to foster in order to promote the export performance and international competitiveness of domestic enterprises.

(2) The breadth of the firm's expertise in several different areas, since large multi-product and multi-competence enterprises are those that have presumably received public funding already in the past and thus previously developed a reliable user-producer relationship with public authorities. This is the aspect that defence authorities look at when they want to finance large enterprises to build up and strengthen technological and military capabilities for national security objectives.

The existence of these two different policy objectives, and the related public funding allocation mechanisms, is as noted above the main point investigated by the model. The current institutional set up in the defence industry typically combines together these two public funding criteria, so that companies may qualify for public funding either if they have a high product quality or if they have a broad competence basis (or both). The next section will ask whether the current "mixed" scenario is better and more efficient than the corresponding alternative "pure" scenarios, in which firms may only receive public funding for one of these two allocation criteria.

A summary and overview of the model (see figure 1) highlights the following two key features of this theoretical framework. First, in any period t, the agents will be sorted in three distinct groups: (1) successful innovators that qualify for public funding (see figure 1, *loop 1*); (2) successful innovators that do not meet the criteria for public support (*loop 2*); (3) unsuccessful performers, which will either undertake a new privately-funded R&D project or imitate by searching a cooperation partner (*loop 3*). Secondly, the overall dynamics of the model, as shown in the next section, depends on the combination of two different mechanisms: (1) a cumulative causation mechanism according to which the best performers will tend to get public support and hence strengthen their market position even further in the future; (2) a catch up mechanism through which less successful companies will be able

to adjust their performance and possibly achieve a leading market position in the future.

4. Variables and indicators

4.1   Target (dependent) variables: Industry-level outcomes

The following four variables are aggregate outcomes of the model, i.e. emergent properties that are observed at the industry-level as the result of micro-level behaviour and agents' interactions. They represent the key variables defining the performance of the defence industry, and thus the main factors we seek to explain in our simulation analysis. The first three variables refer to the policy objective *export performance and international competitiveness* (the main objective of innovation policy), while the fourth indicator refers to the policy objective *military capabilities and national security* (the main objective of defence industrial policy).

Export propensity (%): Number of exporters as a share of the total number of firms in the industry. This is the variable typically highlighted by recent models of firm heterogeneity and international trade [23,24]. As explained in the previous section, only firms that are above a given profitability level are assumed to be able to cover sunk export costs and export their products in foreign markets, whereas most other enterprises will continue to produce only for the domestic market. This variable is typically used as an indicator of the export performance of an industry for a given country.

Export value: A second commonly used indicator of the export performance of an industry is the total value of export in the industry, which is obtained as the sum of all defence firms' export value in any given period t.

Mean product quality: A third indicator of industry competitiveness is provided by the mean product quality in the defence sector, calculated as the industry-level average of the index measuring each defence firm's product quality. The reason for using this indicator has been explained in section 3: our model assumes that the export performance of an enterprise depends on the quality of the product it commercializes. So, there is a close correspondence in our model between the mean product quality and the industry's international competitiveness.

Mean competence breadth: This is the industry-level average of the competence breadth of all firms in the defence market. We use this as an indicator of the second main policy objective investigated in this paper (*military capabilities and national security*). As explained

above, the rationale for choosing this indicator is that national defence authorities – in the attempt to strengthen the military capabilities they need for security reasons – typically provide financial support to defence companies with a broad base of competencies, since these companies are most likely to be able to provide the armed forces with access to the high-end technological expertise that it needs when it acquires new military equipment and support them with a steady supply of spare parts and munitions in times of a national crisis. In sum, a higher average competence breadth in the industry means that there is a large enough pool of capabilities and expertise that national defence authorities may exploit to achieve their military capabilities and national security objective.

4.2   Key explanatory variables (policy strategies and objectives)

The following two parameters describe the key characteristics of the policy environment in which agents operate, which are determined by the policy strategies and objectives pursued by policy makers. They represent the main explanatory variables of interest in our simulation analysis. Our policy scenarios will be constructed by exploring different combinations and configurations of these two parameters.

Public funding criterion I: Product quality threshold: This is the first of the two criteria set by public authorities to grant public support to private defence firms. The indicator ranges on a continuous scale defined on the quality domain between 0 (loose quality requirement, easy to get public funding) to 10 (strict quality requirement, difficult to get public support).

Public funding criterion II: Competence breadth threshold: This is the second requirement for qualifying for public support. The parameter ranges on a continuous scale defined on the innovation hypothesis domain between 0 (narrow technological competence, easy to get public funding for most firms) to 10 (broad technological competence, difficult to get public support for many narrowly specialized companies).

4.3   Other explanatory variables (control factors)

The remaining six parameters do also represent environmental characteristics affecting the industry dynamics and model outcomes. However, they may not be influenced by policy actions in the short-run, so we regard them as control factors and take them as exogenous in our simulation analysis.

Cooperation propensity: This defines the extent to which agents are willing (and able) to cooperate with others in the same market, i.e. their collaboration propensity. This parameter ranges on a continuous scale from 0,50 (lowest cooperation propensity) to 0 (highest propensity).

Success threshold: This indicates the threshold above (below) which firms consider themselves satisfied (not satisfied) with their current market performance (e.g. corresponding to the mean profit level in the industry). The parameter is defined in the profit space ranging from 0 to 12 000. This parameter is largely dependent on the extent and intensity of market competition, i.e. the success threshold is higher (lower) in a more (less) open and competitive market, because agents must compete with a greater (smaller) number of competitors (including foreign firms) in order to maintain their market position. In other words, in a more (less) open and competitive market companies tend to be more (less) demanding because they are aware they face a stronger (weaker) competition.

Number of firms: Total number of enterprises in the market.

Number of products: Total number of products that are sold in the market.

Share of large firms: Number of large enterprises as a percentage of the total number of firms in the market.

Share of end products firms: Number of enterprises that produce final products as a percentage of the total number of firms in the industry.

5. Simulation analysis and results

5.1 Six different policy scenarios

The six policy scenarios we construct differ in terms of two main aspects. First, they differ in terms of the policy strategy adopted by national authorities to finance and support private firms in the defence industry. The "mixed" scenarios are those resembling the current institutional set up, in which policy makers simultaneously pursue two different objectives – fostering international competitiveness (through innovation policy) *and* strengthening military capabilities (through defence industrial policy). As a possible alternative to this mixed policy strategy, it is possible to envisage two alternative "pure" scenarios: "INN" and "DEF". The "INN" scenario (*innovation policy*) denotes the situation in which policy makers only pursue the international competitiveness objective by funding support to strengthen private companies' product quality and export performance. The "MoD" scenario (*defence industrial policy*), by contrast, represents the situation in which national authorities only focus on the military capability and national security objective by financing large multi-product enterprises for developing new products of high military and strategic significance.

Secondly, the policy scenarios we set up differ in terms of the degree of openness and liberalization that characterizes the defence industry. The current situation, as described in section 2, is that the defence industry is typically a close and highly protected market. However, the new EU Directive that is now starting to be implemented by all European countries (including Norway) will in the future introduce a higher degree of openness and liberalization in this sector. Thus, the "EU" scenarios denote a future economic environment characterized by lower protection and greater market liberalization in the defence industry.

In sum, combining together these two dimensions (national policy strategy and EU framework conditions) we outline the following six scenarios:

1. **Basic Mixed:** protected market, mixed policy strategy
2. **Basic INN:** protected market, only innovation policy
3. **Basic DEF:** protected market, only defence industrial policy
4. **EU Mixed:** liberalized market, mixed policy strategy
5. **EU INN:** liberalized market, only innovation policy
6. **EU DEF:** liberalized market, only defence industrial policy

Table 1 reports the values of the parameters that have been used to calibrate the model in these different scenarios. The "basic mixed" scenario is the baseline situation, and it has been set up by calibrating the model in order to fit the dynamics of an industry with an export propensity between 35 and 40%, which corresponds to the real percentage of exporting firms in the Norwegian defence market [25]. The three "EU" scenarios have been obtained by increasing two of the parameters *vis-à-vis* the baseline situation: (1) the product quality threshold (since market liberalization will induce firms to increase their expected profitability requirements to maintain their market position); and (2) the competence breadth threshold (because national defence authorities will inevitably become more restrictive when faced with a larger number of domestic and foreign applicants for public funding in the new EU regime in the future). On the other hand, the "INN" and "DEF" policy strategies have been set up by simply allowing the existence of one criterion for public funding allocation (instead of two as in the "mixed" scenario).

Table 1: Calibration of model parameters

Parameter	Definition domain	Calibration value: Current regime	Calibration value: EU liberalization regime
Product quality threshold	[0; 10]	6	8
Competence breadth threshold	[0; 10]	30	40
Cooperation propensity	[0; 0.50]	0.45	0.45
Success threshold*	[0; 12000]	5000	5000
Number of firms	> 0	300	300
Number of products	> 0	240	240
Share of large firms	> 0	5%	5%
Share of end product firms	> 0	35%	35%

*The success threshold parameter is defined on a monetary metrics in thousands Norwegian Crowns (NOK).

5.2   Simulation results

Figure 2 reports the results of the policy simulation analysis. Each panel of the figure focuses on one of the four industry-level outcome variables (i.e. our target or dependent variables). The first three variables (export propensity, total export value and mean product quality) are used as indicators of the industry's international competitiveness, and hence they measure the effects of innovation policy support (see section 3). The fourth variable (competence breadth) does instead measure the overall pool of technological and military capabilities available in the industry, and it is thus used as an indicator of the effects of defence industrial policy.

In each graph, we report the time path of a given variable for the six different scenarios outlined above and for a 150-run period. We have repeated each exercise for a total of 20 replications in order to make sure that our results are robust to the presence of stochastic shocks related to R&D activities and outcomes. Each point reported in the various graphs in panel 6 is the average of these Monte Carlo replications.

Before comparing the different policy scenarios that may be implemented in the future, it is useful to focus on the current institutional set up – the "Basic mixed" scenario. Figure 2 shows its time path for the four industry-level outcome variables, thus illustrating the basic working of the model. The dynamics of the industry's international competitiveness (as measured by its export propensity, total export value and mean product quality) is rather stable over time, whereas the industry's mean competence level (measuring the achievement of defence and military objectives) increases substantially over time. This means that in the current scenario, a protected market in which national authorities provide public support for achieving both competitiveness and defence objectives, the impacts on the latter is much stronger than on the former. The lack of a visible effect of innovation policy on international competitiveness is due, in our model, to the fact that in a closed and highly protected market the extent of competition, selection and learning effects, the major driving forces of industry dynamics in our model, are limited.

Would a different policy strategy be able to improve these outcomes? The two "pure" scenarios reported in figure 2 – the "basic INN" (innovation policy only) and "basic DEF" (defence industrial policy only) scenarios – suggest that this would indeed be the case. Both the "basic INN" and "basic DEF" experiments lead to a more dynamic path for the industry's export propensity and total export value, thus ensuring a greater level of international competitiveness. As expected, however, these two differ substantially in terms of the impacts they have on the industry's mean product quality and competence breadth

in the long run. A pure innovation policy strategy would increase substantially the market's average product quality (and hence export performance) but also lead to a significant reduction in the industry's competence breadth.

Further, figure 2 also shows that the implementation of the new EU Directive will introduce an important boost-effect in the model. Looking at the three EU scenarios, in fact, we note that market liberalization will increase the relative impact of innovation policy on the defence industry's export performance and international competitiveness. As noted above, the intuition behind this result is in line with recent models of firm heterogeneity and international trade: in an open and liberalized market, the competition, selection and learning effects that drive the aggregate dynamics of the industry are magnified, so that defence firms will on average become more innovative, more prone to inter-firm collaborations and knowledge sharing, and hence better suited to the requirements of international competition [26,27].

Figure 2: Six policy scenarios: Simulation results
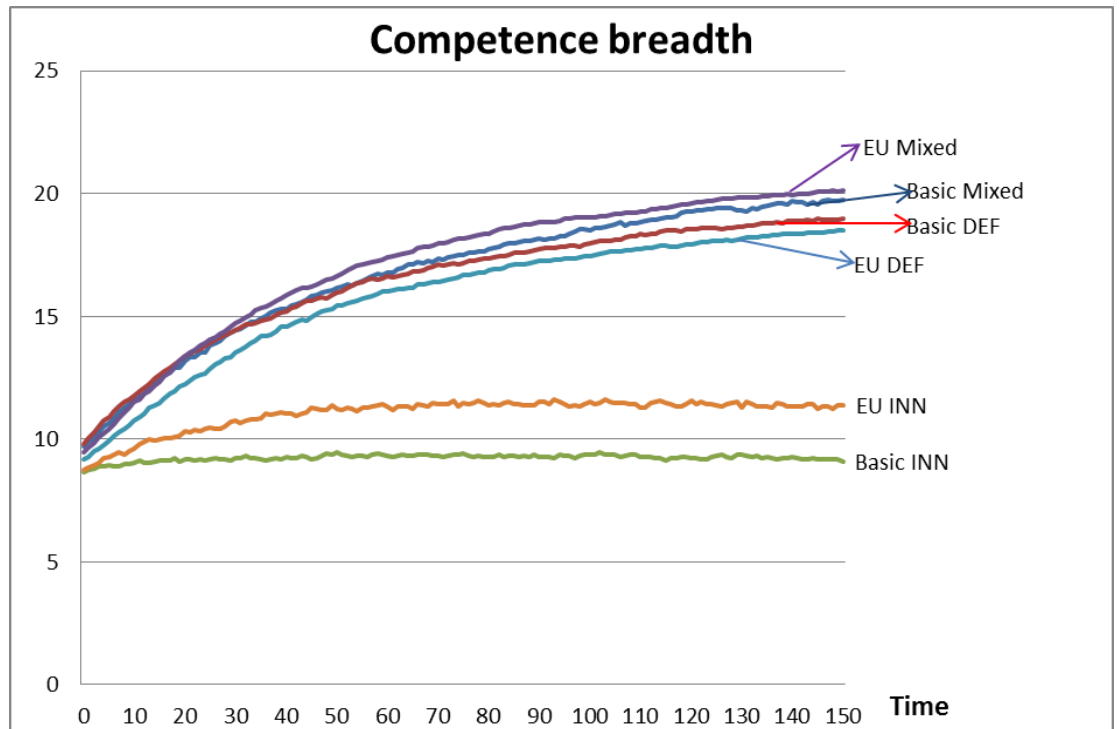
Total export value

Product quality
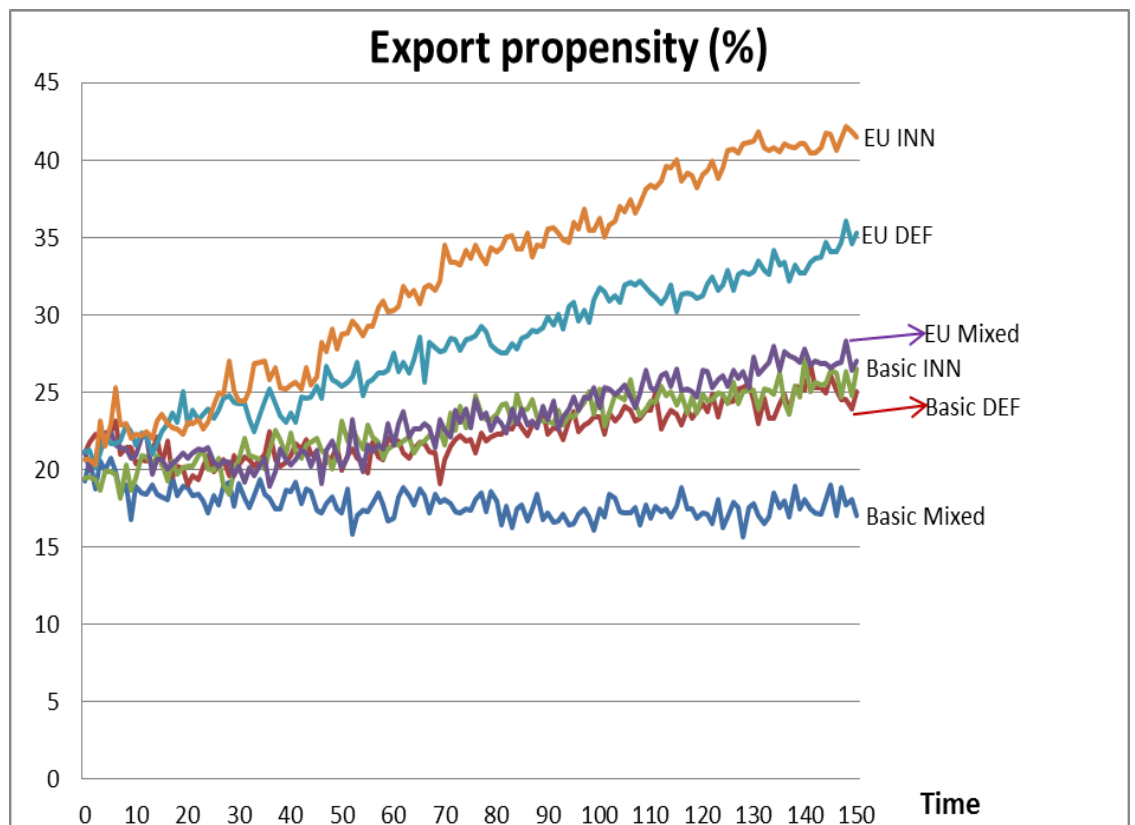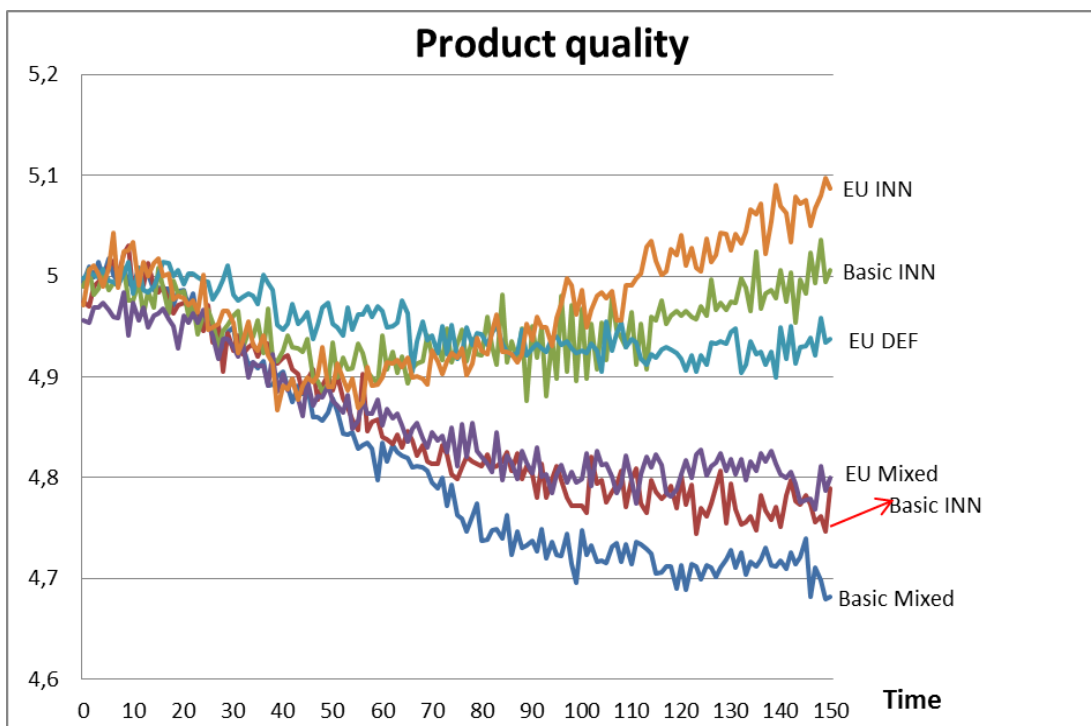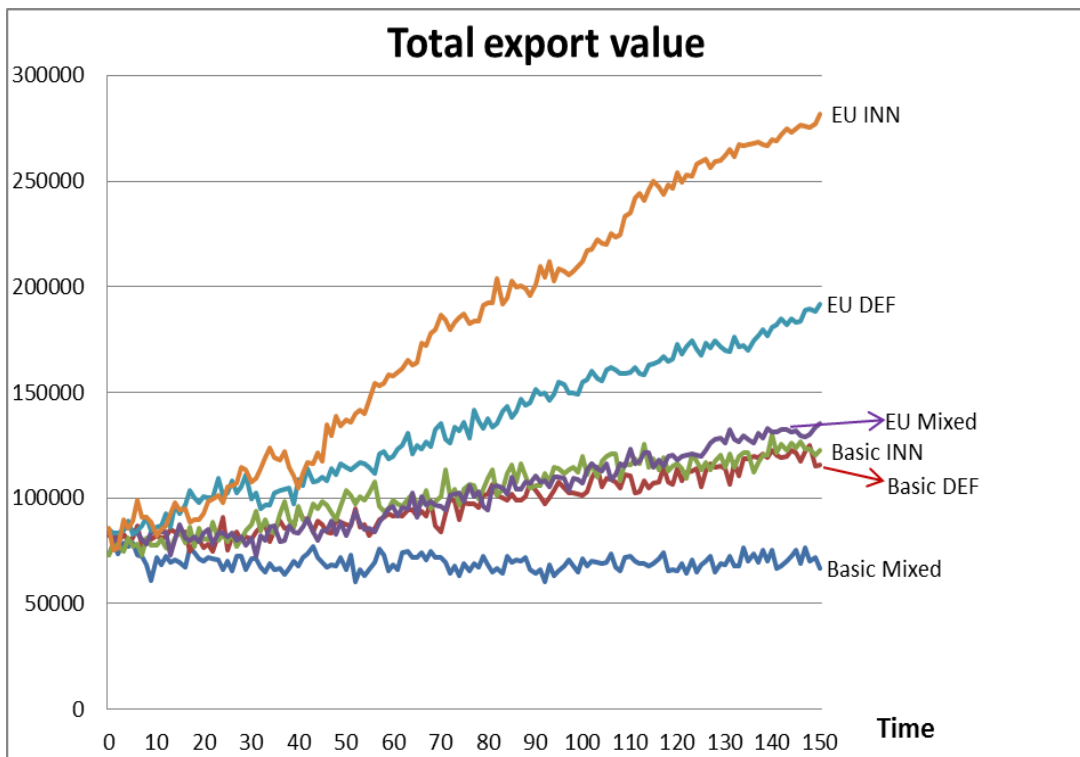
Figure 3 provides a more explicit analysis of the trade-off between innovation and defence industrial policy. The figure plots these two dimensions and policy objectives against each other – i.e. it reports the values of the industry's export performance (propensity and total export value) *versus* its competence breadth for our six scenarios at two specific time points of the simulation run, the medium term ($t = 50$) and the long term ($t = 150$). The purpose of this exercise is to provide an intuitive illustration of the trade-off and possible contrast between these policy objectives, and evaluate what the most efficient policy strategy is. The results for $t = 50$ and $t = 150$ are largely in line with each other. First, focusing on the three "basic" (or current) scenarios, we notice two main patterns.

(1) The *pure* scenario "Basic DEF" (defence policy support only) is always superior (more Pareto efficient) than the "Basic mixed" strategy: if national authorities decided to shift from the current mixed policy strategy to the pure DEF strategy, the industry's competence breadth would remain at approximately the same level, but the export performance would increase substantially. In our model, this result is explained by the fact that defence companies, when they find it harder to receive public support to finance their innovation activities (e.g. because of the reduced innovation policy support), would be penalized in the short run but would, in the medium-longer term, gradually improve their performance by setting up and managing their own pri-

vately-funded R&D projects as well as exploiting external knowledge through inter-firm collaborations.

(2) In the current regime, there is no clear and visible trade-off between the two pure strategies "Basic DEF" and "Basic INN"; by contrast, the former policy strategy seems to be always superior (more Pareto efficient) than the latter. In fact, the plots in figure 2 show that the shift from the "Basic INN" to the "Basic DEF" leads to a substantial increase in the industry's competence breadth (strengthening of military and defence capabilities) but only a small and negligible decline in the export performance.

Do the same results also hold for the three EU liberalization scenarios? Figure 2 indicates that this is arguably the case for the first pattern: the "EU DEF" pure strategy leads to a better export performance, whereas the "EU mixed" scenario only brings a marginal increase in the competence breadth. The former (pure) strategy is therefore superior to the latter (mixed).

However, the second pattern noted above is affected significantly by the EU liberalization process: in the long-run ($t = 150$), a visible trade-off between the two pure strategies emerges. In fact, innovation policy support ("EU INN") will eventually lead to a sizeable increase in the industry's export performance, whereas defence policy support ("EU DEF") would make it possible to strengthen the sector's competence breadth substantially. In such a situation, the two policy objectives are clearly in contrast with each other, and the choice whether to focus on one or the other should be taken on purely political grounds.
In short, our simulation analysis can be briefly summarized by the following propositions.

Result 1: Pareto efficiency of *pure* vs. *mixed* policy strategies. A *pure* scenario in which national authorities focus on, and only provide support for, the achievement of defence and security objectives is always superior (more Pareto efficient) to the corresponding *mixed* strategy in which policy makers simultaneously pursue both defence *and* international competitiveness objectives.

Result 2: The trade-off between pure policy strategies in the new EU liberalization regime. In the new EU liberalization regime, there will emerge a stronger and more visible trade-off between the two different policy objectives – national security and defence *versus* international competitiveness – so that policy makers will have to set up a clear agenda focusing on only one of those objectives and neglecting the other.

Figure 3: The trade-off between different policy objectives: Export performance *versus* military capability building (competence breadth). A comparison of the six policy scenarios at t=50 and t=150.
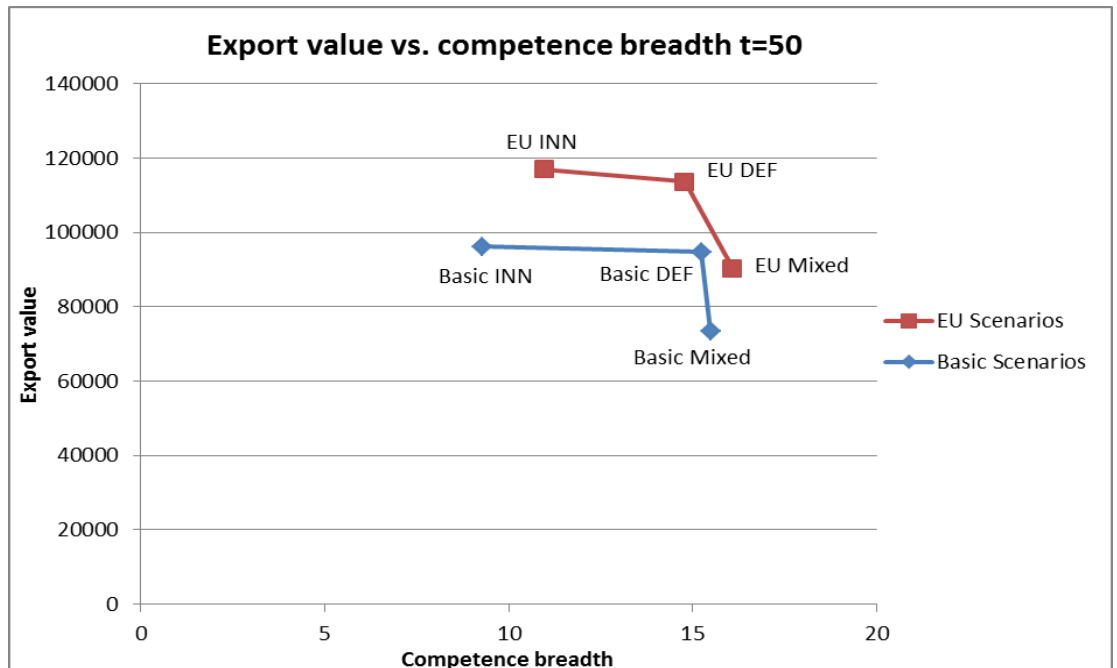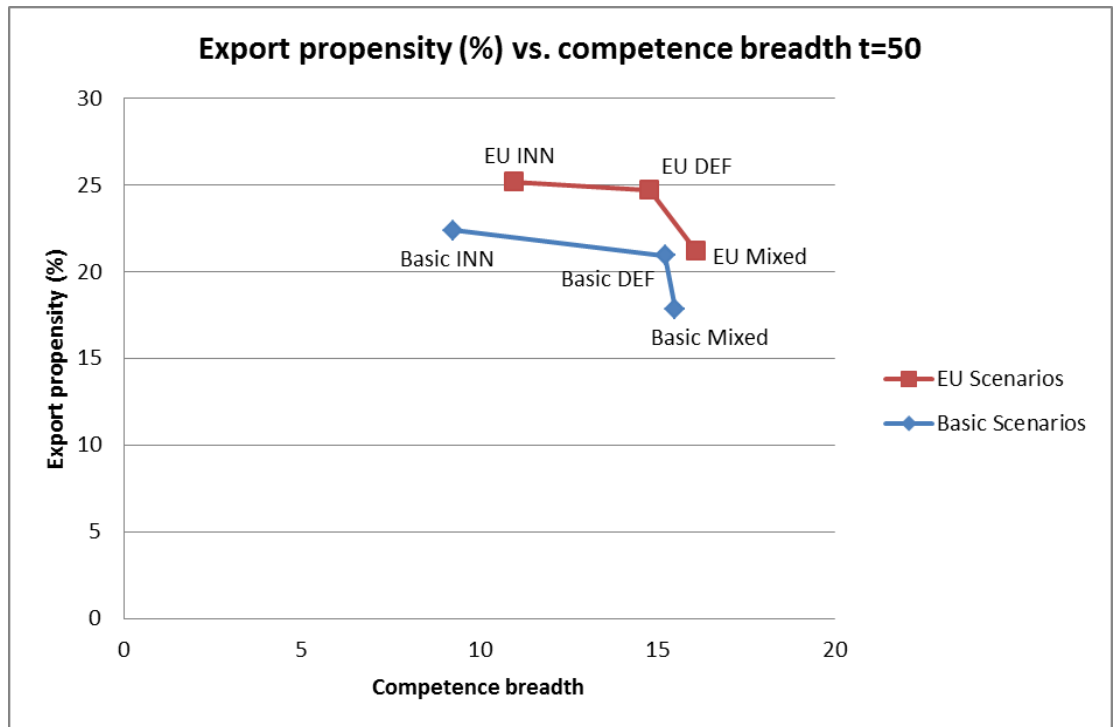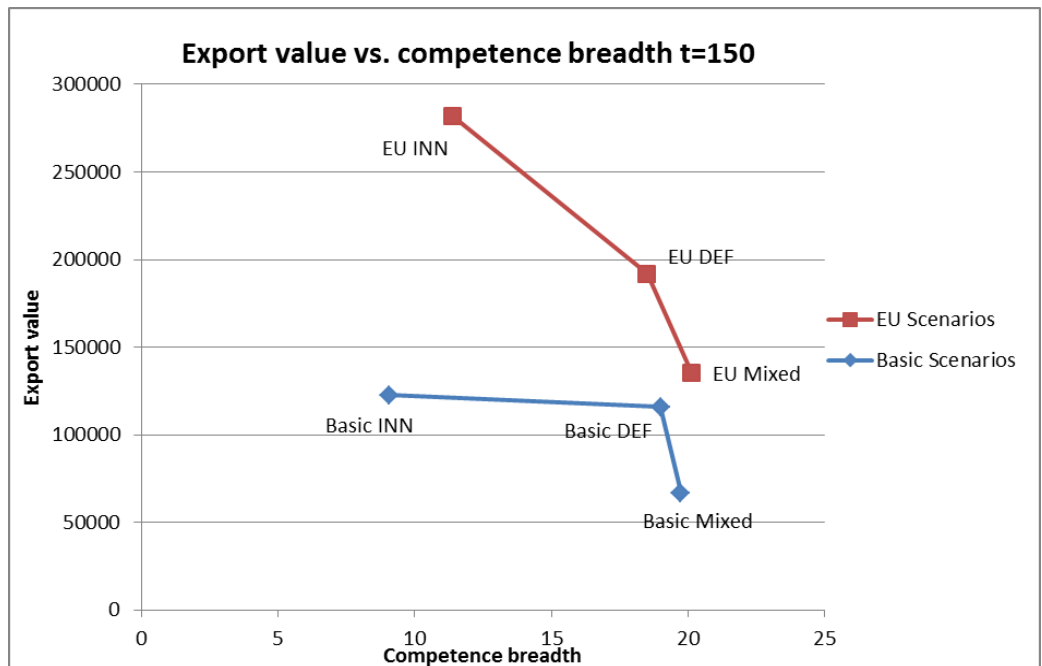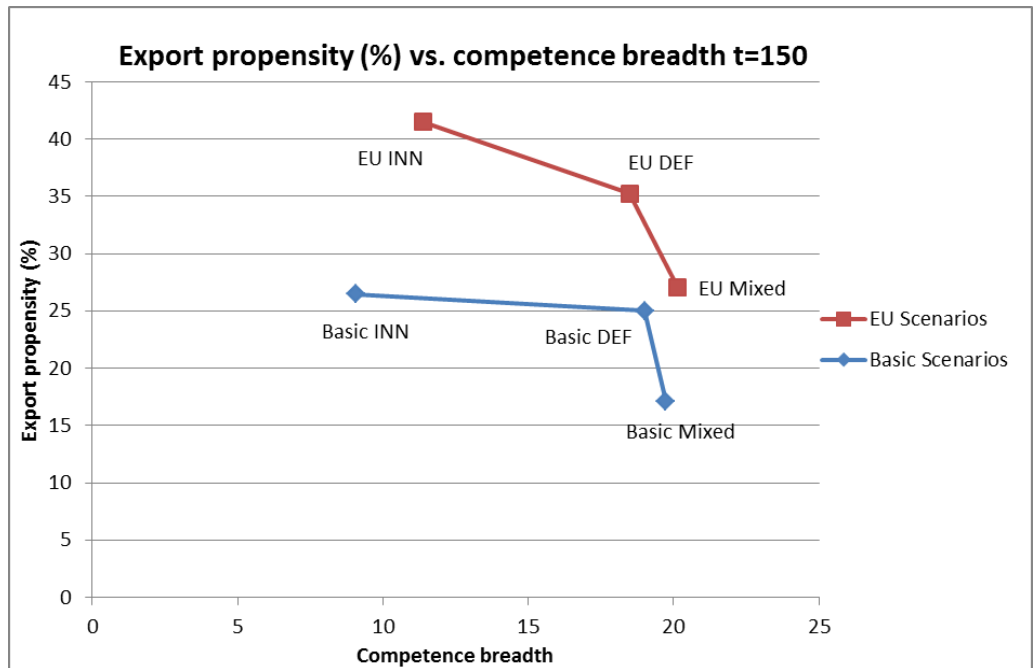
6.Conclusions and policy implications

This paper set out to investigate innovation and defence industrial policy in the context of a liberalizing market. It aimed to (i) investigate the trade-off and contrasting effects of two different policy objectives with regards to the domestic defence industry – strengthening military capabilities *versus* fostering international competitiveness – and to (ii) examine whether and to what extent a future liberalization of the European defence market would affect this trade-off (as a consequence of the implementation of the new EU Directive).

In terms of the trade-off between strengthening military capabilities and fostering international competitiveness, the simulation analysis found that there was a clear contrast between innovation and defence industrial policies, in the sense that pursing innovation policies would increase international competitiveness at the expense of military capabilities and vice versa. Nevertheless, the loss of international competitiveness was, in the basic scenario, fairly small compared to the gains in military capabilities (a few per cent loss in export propensity resulted in an almost 50% increase in competence breadth). This implies that if strengthening military capabilities is an important objective for the government, pursuing a "pure" defence industrial policy might be the best policy strategy. The simulation analysis also found that pursuing both innovation and defence industrial policies simultaneously resulted in a negligible improvement in military capabilities and a dramatic decline in international competitiveness, compared to pursuing defence industrial policies alone. This implies that a "mixed" strategy seems to be a poor strategy under all conceivable circumstances.

In terms of the impact of a future liberalization of the European defence market, the simulation analysis showed that the trade-off between innovation and defence industrial policy was not only maintained, but that it increased – in the sense that improving military capabilities came at a greater cost to international competitiveness. This implies that, in the future EU liberalization scenario, the government will have to reconsider its policy agenda and decide whether it is more important to focus on defence and security objectives (strengthening military capabilities of domestic companies) or to support the international competitiveness of the industry. As the European market gets increasingly liberalized, the trade-off between the two will get stronger and the policy agenda will have to be adjusted accordingly. Similarly to the basic scenario, the simulation analysis also found that pursuing both innovation and defence industrial policies simultaneously re-

sulted in a small improvement in military capabilities, but at the expense of a dramatic decline in international competitiveness. This implies that a "mixed" strategy in a liberalized market will continue to be a less Pareto efficient policy strategy.

Looking at the overall effects of the implementation of the new EU directive, our results indicate that it will strengthen the Norwegian defence industry both in terms of international competitiveness and military capabilities. International competitiveness will increase significantly for all policy scenarios and military capabilities will be fostered slightly in two of the policy scenarios (innovation policy and mixed) and decline slightly in the last (defence industrial policy). This implies that for all policy scenarios considered in this paper (with the only exception of the 'pure' defence industrial policy strategy), the implementation of the EU directive will introduce in the Norwegian defence sector a higher degree of international competitiveness given the same level of domestic military capabilities.

Although this article has investigated the trade-offs between different policy strategies in the defence sector, the insights gained through the analysis might be relevant for other sectors of the economy as well. We believe that the method used in this paper can be especially useful for analysing and forecasting developments in industries where there is a dynamic, complex and conflicting relationship between economically efficient production and important social externalities. Food production could be one example, where some farming activities can contribute to tourism and sustainable development by maintaining the cultural landscape (preventing overgrowth and creating a "rural atmosphere"). Since the productivity and organization of these farming activities can change over time, they need to be analysed in a framework that look at the trade-offs between their economic efficiency and positive externalities in a way that also takes into account the effects of technological change and varying market conditions. Other applications might be energy production, where some means of energy production are less efficient, but more reliable or environmentally friendly; or the pharmaceutical industry, where the development of some medications for tropical illnesses are less profitable, but might create a healthier and more peaceful world.

Acknowledgment

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