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Firms, Innovation, Export and the Policy Regime: An Agent-based Model of the Defence Industry

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Abstract

The defence industry has traditionally been a heavily regulated and protected market. A new EU Directive being implemented in Norway, January 2012, intends to reform the European defence market towards a higher degree of openness and liberalization. It is therefore vital for the Norwegian Government and national defence authorities to explore the impacts this new EU Directive will have in the near future. This thesis presents a computational agent-based model of the Norwegian defence industry. The purpose is to study how defence firms' innovative activities affect their export performance, and to investigate the extent to which public policies, and specifically the implementation of the new EU Directive, will shape conditions for firms innovation and export activities. It provides a novel theoretical framework drawing insights from innovation systems theory, evolutionary economics and mainstream international economic models. The framework is used to construct an agent-based model, for the first time applied in the context of the defence industry, in which knowledge and innovation are the driving force of companies' international and export activities. In order to investigate the possible effects of the implementation of the new EU Directive in Norway, the simulation analysis presents five future policy scenarios and outlines the effect of different public policy strategies on the Norwegian defence industry measured by the future export performance of firms. The main findings are that a change towards more openness, competition and liberalization of the Norwegian defence market will have a positive impact on firms' innovative capabilities and will increase their export performance.

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1 Introduction

1.1 Background and objectives

Firms in the international defence industry typically spend a substantial amount of resources on research and development (R&D) and innovation activities in order to sustain their economic performance and international competitiveness in foreign markets (Mowery 2010; Wicken 1985). The European defence industry however, is currently characterized by a low international competitiveness, high national protection of domestic markets and frequent duplications of R&D and production of materials in different national markets. Since defence budgets have been decreasing in the last decades and R&D costs increasing, the defence industry in Europe needs to consolidate and strengthen its position in international markets.

In order to address this situation, a new EU Directive – *The European Union's Defence and Security Procurement Directive 2009/81/EC* – has recently been introduced. This EU Directive is currently being implemented by European Member States, and will be implemented in Norway from 01.01.2012. The aim of the Directive is to create a more open and more competitive defence market in the European Economic Area (EEA) by, among other means, changing public procurement regulations and strategies. It is therefore vital for the Norwegian Government and national defence authorities to explore the impacts this new EU Directive will have in the near future, and how different ways and paces of implementation of it will affect defence firms' innovation and international activities.

The first objective of this thesis is to explore how the export performance of firms in the Norwegian defence industry is affected by firms' innovative capability in the current public procurement regime and protected market environment, and the second objective is to study how the changes in this policy and market environment, brought by the new EU Directive, will affect the relationship between firms' innovative capabilities and export performance.

In order to support a study on the interactions between innovative capability and export performance in the defence industry, the thesis will be based on theories from sectoral innovation systems (Malerba 2005) and evolutionary economics (Fagerberg 2003; Schumpeter 1937). The theoretical framework is broad and addresses two main gaps in the existing literature. The SIS literature is typically a descriptive framework with a strong historic component, but arguably, little analytical content. Introducing insights from evolutionary economics models into the SIS framework may contribute to address this gap. The second gap address the evolutionary economics literature which has so far mostly focused on the impacts of innovation on firms' productivity and profitability growth, but has provided little insights on the possible determinants of enterprises' export performance. For this reason, theory and models from the current mainstream international economics literature (Melitz 2003) are added into our framework to strengthen it and pave the way for a novel model.

Based on these theoretical framework and extensions, the thesis develops a novel agent-based computational model of the Norwegian military-industrial-political complex (Hartley 2007), and carries out a careful calibration of it to simulate the Norwegian defence industry. It emphasizes firm behavior, their knowledge base, the particular institutions of the defence sector and public involvement. In the model, knowledge and innovation are the driving forces of firms' export performance. An agent-based simulation model implies that the behavior of micro-level agents (defence firms) are responsible for the dynamics in the model and that macro-level market performance is an emerging property of the agents' behaviors. This type of model has previously not been applied to the defence industry and is thus a novel contribution to the academic field of innovation studies.

Simulation results indicate that the current public policy regime limits firms' innovative capabilities and this in turn may negatively affect firms' export performance. In a change towards increasingly open markets, more competition may in the future induce higher innovation activity and consequently an increased export performance in the Norwegian defence industry. More intra-industry and cross country cooperation could occur and this would allow firms to take advantage of knowledge spillovers and have a positive effect on industry performance and export propensity. Further, our results also suggest a possible trade-off that is relevant for national policy makers. If Norwegian defence authorities want to promote 'national champions' (large oligopolistic firms) this would not increase industry export performance, as measured by the number of Norwegian firms participating in export activities. However, should they choose to support firms to specialize and focus on core competences this will have a positive effect on the export performance in the defence industry.

1.2 Overview of thesis

The next chapter gives an overview of the military-industrial-political complex by presenting its structural layout, technological domain and the government policy framework. Furthermore, it discusses the EU Directive with some of its consequences is discussed, before the research question of the thesis is presented at the end.

Chapter three provides the foundations of the theoretical framework in the thesis and presents sectoral innovation system theory, evolutionary economic theory and inspiration from mainstream neo-classic economy as one interwoven theoretical framework. It will also discuss the propriety of using sectoral innovation systems as part of the framework.

Chapter four describes the methodology of agent-based modeling. It explains in detail how agent-based modeling works and how it is done. The chapter also includes a discussion on advantages and disadvantages with this methodology.

Chapter five presents the model which has been developed with the thesis. It includes a description of the defence firms as micro-level agents, along with a description of the market environment and conditions for innovation. How the model is calibrated in addition to what type of empirical data the model provides is also reviewed.

Chapter six presents the empirical findings and analysis of the data. Three types of analysis are performed. The first analysis is qualitative and focuses on properties of the model. The second is quantitative and also studies properties of the model. The last is a qualitative analysis of six policy scenarios. These scenarios are the main empirical findings of the thesis.

Chapter seven summarizes the thesis, answers the research question and provides policy implications, contributions to innovation studies and limitations with suggestions for further research.

2 The Norwegian military-industrial-political complex

2.1 The nature of the military-industrial-political complex

2.1.1 Introduction

In Norway many agents are involved in the process of buying arms to the military, produce defence material and make political guidelines. All those who are involved in these actions make up the military-industrial-political complex.

"The military-industrial-political complex comprises interest groups of the Armed Forces and national Defence Departments, producer groups of major prime contractors and politicians with an interest in defence spending (…)" (Hartley 2007, p.1155)

The national defence industry, or defence industrial base, is part of this military-industrial-political complex. In order to lay the foundations for a model of the military-industrial-political complex this chapter aims to provide a brief overview of current knowledge with an emphasis on the Norwegian defence industrial base and related public policies.

2.1.2 Definition of the defence industrial base

In the international literature on the defence industrial base (DIB), also referred to as the defence industry, there are many differing definitions of what is meant by the term 'defence industrial base'. Depending on the theoretical definition a small or large number of firms could be included with or without civil production. It seems that the context in which the definition is used is important. For this reason definitions can vary to a great extent.

For the purpose of this thesis the DIB is viewed as a sectoral innovation system. The definition of a sectoral innovation system will be provided later, but it provides a useful framework with which to treat the Norwegian defence industry. This framework provides the basis for the outline of this chapter.

Examples of definitions: (1) The DIB consists of all firms who supply defence material, or defence related materials, and corresponding technology and services (Fevolden, Andås, and Christiansen 2009, p.12); (2) "the defence industrial base consists of those industrial assets which provide key elements of military power and national security: such assets demand special consideration by government"; (3) "the nation's defence industry 'embraces all defence suppliers that create value, employment, technology or intellectual assets in the country'" (Hartley 2007, p.1141).

In fact Hartley points out that a definition could give a misleading impression of the defence industrial base as a single homogenous entity. As shown below, this is not the case. However, in a Norwegian context it is more useful to provide an operational definition, i.e. all firms who are members of 'Forsvars og Sikkerhetsindustriens interesseorganisasjon' (FSi). The Norwegian Defence Research Establishment (FFI) recently used the definition: All firms who are positioned within the defence market and contribute to added value in Norway (Fevolden and Tvetbråten 2011, p.16). The number of firms comprised by members of FSi and the other operational definition provided by FFI are about the same. There is 114 FSi members and 121 firms used in the FFI statistical publication (Fevolden and Tvetbråten 2011, p.15, 18).

2.2 Description of the Norwegian defence industrial base

2.2.1 The defence industrial base market environment

In order to understand the environment the defence industrial base operates within, it is important to first understand the defence market. This is a closed, highly protected and politically influenced market. With only one costumer per country, and often just one or two suppliers of a product in each country, the competition is very limited. The Norwegian government has a key role in defining defence firms' access to international markets, R&D activities, level of technology and ability to compete with other firms (Forsvarsdepartement 2006, p.14). In this way the defence market is very different from other civilian markets.

In addition to the peculiar market conditions, there is also a large heterogeneity within the defence industry. Some few firms are large, often referred to as the big four (Kongsberg, Nammo, Thales and Simrad Optronics), and most others are SMBs (Small Medium sized Businesses). They produce a great variety of products like clothes, software, electronics, ammunition and large integrated weapon systems. This implies a complex industry with very differing knowledge bases.

2.2.2 The structural layout

The main bodies of Norwegian companies are located in the eastern part of southern Norway and in western Norway. The majority of companies define themselves as working with either information and communications technology (ICT) (23%) or systems integration (20%). As mentioned above, there are a few large companies and many small ones. In total the operational definitions above include some 114 - 120 defence firms. The large firms have 250 or more employees in defence related work. 81 of the companies have 10 or less employees.

In average 46% of the production in the companies is defence related, the rest is civilian production. Some have only defence related products and others have almost none. The Norwegian defence industry is highly concentrated with a concentration index (C5) of 0.75. This means that the five firms with biggest profit take 75% of the total profit in the market. The high concentration is typical for markets with a few large oligopolistic firms, which is the case for the Norwegian defence industry.

The level of competition in the domestic market (Norway) is considered as low. SMBs reported some competitors and the large firms almost no competitors. However, the level of competition intensity is moderate for SMBs and quite high for large companies in the domestic market. In foreign markets the situation is reversed with five to ten times as many competitors, and the competition is very high for all companies. To summarize, the competition is experienced as higher on the international market. The defence industry regarded the level of competition as positive for product development and export ability.

In general SMBs cooperate less with other firms than large companies in Norway. The cooperation is highest with international competitors, then decreasing for national and even more so with regional competitors. In terms of cooperation with competitors, it is in the field of industrial framework conditions, R&D, simulation and training where the large companies cooperated the most. In terms of purchases and distribution, they did not cooperate much. Large firms describe a close relationship with research institutions such as FFI. In sum, there is a modest level of cooperation in Norway.

2.2.3 Economic figures

Global military spending is estimated at well above US$1 trillion each year (Markowski, Hall, and Wylie 2010, p.83). In Norway the turnover in the defence industry is estimated at NOK12.2 billion, with government spending at NOK9-10 billion yearly. Of this turnover NOK5.3 billion is export, making the export share of turnover 43.4%. The number of exporting firms is 38%. The big firms tend to have larger export intensity whereas for SMBs the intensity varies, but are in general lower.

The total R&D investment is NOK1.3 billion. For large firms there is a small percentage of internal R&D and high percentage of costumer financed R&D. In SMBs the situation is reversed and they also tend to invest more in R&D relative to their size (Fevolden and Tvetbråten 2011, p.23).

Looking at the economic figures, Norway as a small country is a big exporter and it is important for the defence industry to invest heavily in R&D.

2.2.4 Technology, competence and knowledge

A survey of existing competence and knowledge

FFI has carried out a survey of the defence industry where they determine what knowledge and competence there is available. To help them they have used the European Defence Agency's Technology Taxonomy (EDA 2006). Here knowledge is defined as what a firm knows something about and competence is defined as what the firm can do engineering wise.

The Norwegian defence industry has 8 strategic military technology competence fields. They are: Information and Communications Technology, Systems Integration, Missile Technology, Underwater Technology and Sensors, Simulation Technology, Weapons and Rocket Technology along with ammunition and explosives, Material Technology and Maritime Technology. (Forsvarsdepartement 2006, p.12) It is obvious that these strategic fields represent a considerable breadth. Indeed findings by FFI suggest the DIB has a very broad knowledge and competence base. 2/3 of the EDA Technology Taxonomy is covered by the Norwegian defence industry.

Primarily, the Norwegian defence industry has a competitive advantage in ICT and systems integration. ICT is in this context software and encryption technology. Systems integration is the ability to implement a large number of components into a larger product platform like advanced weapon systems. However, only four large firms where viewed as being capable of handling systems integration and there are large gaps in the knowledge and competence base. For example, semiconductors, electronic warfare and sensor systems are not included in the knowledge and competence base.

The flow of competence and knowledge

Looking at the flow of competence and knowledge in the Norwegian defence industry, there is a flow of knowledge between the large defence companies, contractors and costumers. Contractors are seen as an important source of complementary knowledge and source of innovation and new knowledge. Norwegian contractors are used for specific merchandise and high quality. However, mostly foreign contractors are used. SMBs recruit from the Norwegian military and this could be seen as a transfer of knowledge, but they are probably too small to benefit from cooperation with research institutions. There is some evidence of clustering amongst large companies with beneficial effects due to cooperation. This is not the case for SMBs in the context of Norway, since they report a low level of cooperation in Norway. They do however cooperate to a greater extent on a global scale with their foreign partners.

Innovation and research

Doing innovation and R&D is highly important to the Norwegian defence industry and receives a lot of focus and capital. 58% in average reported innovations the last three years compared to 21% for all industries. In general the number is high, independent of company size. 52% of the companies reported they do in-house R&D compared to 12% for all industries (Fevolden, Andås, and Christiansen 2009, p.14). The home market costumer is seen as the most important contributor to product development, followed by the export market costumers, internal R&D and lastly the mother company(Fevolden, Christiansen, and Karlsen 2011, p.32). The pressure to continually innovate is high in order to include cutting edge technology in their products and thus being capable of competing with firms abroad and export.

2.3 Institutions: Government policy framework

2.3.1 Defence related public procurement

The defence policy is important to any nation. A country has a moral obligation to protect its people. In order to maintain a military force a secure supply of defence materials is needed. For this reason many large nations has a big defence industry, in order to supply their armed forces with all the material they need. As a consequence larger countries often have a public procurement policy where they prefer to buy products from their own defence industry rather than importing the products.

This functions as a protective trade barrier. If a nation is self-sustained in relation to defence products, it has no incentive to import any of the goods already domestically available. The reason for this is the strategic importance of maintaining a domestic defence market to secure future supplies. Prices on foreign products could be lower, but it is still more important to buy domestic products.

Smaller countries cannot afford to maintain a large defence industry covering all their supply needs. They must rely on a smaller defence industry with more specialized products. Small countries procure what they can from their own industry and import what they must from other countries. However, for the specialized DIB in a small country, to survive, it needs to export. Small countries do not buy enough to sustain its own industry. Unfortunately for these industries, it is hard to gain access to a defence market abroad with effective trade barriers.

As implied by the term military-industrial-political complex, there are many agents involved in the policy framework for public procurement. The Ministry of Defence (MoD) is the most important agent with its direct impacts through regulation of the DIBs framework conditions, but there are several others. The Ministry of Trade and Industry with notable support agents such as Innovation Norway fund different projects. The Ministry of Education and Research also funds defence related research through a program called SKATTEFUNN and the support agent Norwegian Research Council. In addition, the Ministry of Local Government and Regional Development have programs for local funding of the defence industry.

The key points in the framework conditions for the Norwegian defence industry are found in '*Stortingsmelding nr. 38: Forsvaret og industrien – strategiske partnere*' (Forsvarsdepartement 2006). It outlines that early dialog with the defence industry concerning the governments needs are important. In addition, all alternative methods for purchase must be considered. This includes multinational solutions, rent and lease; buy secondhand, industry cooperation, or a combination of these. There is a specific set of guidelines for public procurement called '*Anskaffelsesregelverk for* *forsvarssektoren*' (ARF). On top of this, regulation, political considerations and subsequently decisions are allowed when the purchases is of strategic industrial interest.

2.3.2 Industrial cooperation (Offsets)

To overcome the problem of effective trade barriers many countries has implemented the use of offset as part of their public procurement policy. When a procurement of some size is made in Norway, that is defence material the state acquires abroad for more than NOK50 million, the government sign an offset agreement. This agreement is between the state and the foreign company. The essence of an offset agreement is that the foreign company must re-purchase goods in the buying nation for a percentage of the contract sum. If Norway purchases helicopters from NHIndustries in France, the state of Norway and NHIndustries first sign an offset agreement. In this agreement NHIndustries obligate themselves to purchase goods from Norwegian firms for a sum specified in the contract agreement. The purchases from Norwegian firms by NHIndustries must be approved by the Norwegian government to deduct it from the remaining sum in the offset agreement.

Norwegian offset policy

This offset regime has a strategic use and the policy differs from country to country. In Norway the offset sum is set to 100% of the contract value. At least 50% must be spent on products, R&D or technology transfer from areas of the defence industry Norway has deemed strategically important. The remainder must be spent within other areas of the defence industry. The offset agreement includes the use of factors from 1-5. If NHIndustries were to spend NOK20 million on goods from a Norwegian firm, the right conditions could invoke the use of for example a factor of 3. Thus, 20 million NOK times a factor of 3 equal NOK60 million to be deducted from NHIndustries' remaining offset obligation. Money spent in SMBs has a higher factor than for large firms. Certain types of goods, R&D and technology transfer also has higher factors depending on the strategic importance to the Norwegian defence industry. These factors allow the Norwegian government to direct money from offset agreements to strategic areas.

In many other countries they practice the offset regime in a similar manner to Norway. However, in some countries the offset obligation is funneled into e.g. infrastructure rather than their own defence industry. How offset is practiced varies from country to country, but in Norway it is considered an important policy tool for the Norwegian defence industry.

Advantages and drawbacks of the offset regime

The commonly used argument for having an offset regime is to provide access to foreign market for the domestic defence industry. Due to trade barriers, it is considered hard to compete on the international markets. The offset regime allows for considerable revenues from export.

On the other hand, there are several drawbacks. Any firm in the domestic market is usually almost the sole producer of a given product; at least in the case of the big companies. Their pricing is not necessarily tuned to compete with other firms. When much of the revenues come from public procurement, or offset agreements, there are few strong incentives to keep the prices competitive. Since the foreign company has to perform offset purchases they do not necessarily find exactly what they need either. In addition, there are many administrative costs related to administrating the offset regime and the foreign producer would be better off choosing more freely their sub-contractors. In a report from FFI the added cost in Spain is considered to be 7-8% and 2.6-2.9% in the Netherlands (Bjørk 2006, p.35, 36). The difference is due to a stronger offset regulation in Spain, more similar to the Norwegian enforcement of the regime. However, the report from the Netherlands indicates that they gained 36 times the added cost of the offset regime in revenues by having the offset regime, though this number needs careful consideration.

2.4 The EU directive 2009/81 and market liberalization

The past couple of decades have seen a need for the DIB in Europe to consolidate. Budget cuts and higher production costs in the defence industry is the reasons for this. In order to address the situation a directive in EU has been passed and enters into effect this year. The directive is called '*The European Union's Defence and Security Procurement Directive 2009/81/EC*'. The EU commission, large EU countries and the industry is responsible for this directive direct or implicit (Guay and Callum 2002, p.767).

For countries in the EU the Directive is implemented in 2011. In Norway it is implemented from 01.01.2012. The aim of the Directive is to create an open defence market in the European Economic Area (EEA) and abolish in whole or at least parts the offset regime practiced today. This includes perhaps third-party countries as well, but this has not been properly resolved yet since there needs to be established a certain practice first. The directive includes third-party countries, but the defence industry in Norway and probably the rest of the EEA has no desire of this. Including third-party countries means that it should apply to agreements made between a member state of EEA and a none-EEA member. For example if Norway wants to make an agreement with some country in South-America, this directive would apply.

The effect of the Directive is that when a state wants to procure defence materials it cannot any longer choose from whom they want to buy as freely as before, and they cannot demand an offset agreement. If Norway wants to buy something, they would have to have an open tender in the EEA. The company who makes the best bid wins the contract without offset obligations and all foreign or domestic firms compete on an equal basis. Competition is seen as the best policy tool to provide cheaper defence material. The EU-directive is implemented as an answer to dwindling defence budgets, company mergers and consolidations across country borders, and increased development costs due to more technologically advanced products. Since it has not been taken into real use yet, there are many uncertainties related to the directive and how it should be practiced.

Advantages and drawbacks with the directive

A natural expected consequence of the directive is increased opportunity for export. With an open market any Norwegian defence firm can compete to be supplier of a given product within the EEA. This should open up the defence market and be seen as an opportunity for growth.

On the other hand, there are real and potential drawbacks. With the directive, the Norwegian government is no longer able to use public procurement of defence material as a policy to help the defence industry in the same manner as before. It cannot choose foreign suppliers which could offer beneficial offset purchases to the Norwegian DIB, and it cannot make sure strategically important defence industrial areas get contracts in the future. Firms will have to rely on winning contracts abroad to make up for the loss of offset related sales.

The Norwegian DIB fears, that in a worst case scenario, the domestic firms in the EEA will still win the contracts in their home markets and those Norwegian firms will lose the offset related sales as well. They fear the market will not be a truly open market, but that EEA nations will manage to circumvent the directive somehow when it suits them. The industry argues that you cannot change this regime overnight, and this could be true in a transitional period.

The future of defence public procurement policy

There are exceptions to the Directive. Extremely demanding requirements for importance of supply and national sovereignty can be excepted when it is strictly necessary to go beyond the Directive. Each nation must be prepared to prove this in court should they choose to ignore the Directive. Other exceptions are government to government purchases, secret services and perhaps most importantly multi-national cooperation projects which includes R&D. For this reason multi-national cooperation projects with R&D is seen as the way to exercise a public procurement policy that ensure a domestic defence industry. In these kinds of projects several nations opts to develop a product together. They can choose which firms and on what conditions they may participate. In addition, the development must include a R&D phase.

2.5 Stylized facts of the military-industrial-political complex

The methodology of this thesis is to create a computational model of the Norwegian military-industrial-political complex. Based on the presentation of the complex in this chapter some key stylized facts needs to be characterized. These facts are the building stones upon which the model is based. They determine how the model functions and how it is developed.

Stylized fact 1: Firm heterogeneity

Firms in the DIB are highly heterogeneous as has been shown through the diverse possible definitions and the broad competence and knowledge base. Particularly there are some large oligopolistic firms which co-exist with a larger number of more specialized suppliers of defence related material.

Stylized fact 2: Stable and concentrated structure

The DIB has a very stable structure with few entries and exits compared to other sectors. The defence industry is characterized by a high concentration and an oligopolistic structure where large firms exploit their position through high capital intensity (Lichtenberg 2007). For this reason the Norwegian DIB appears to have a close resemblance to a Schumpeter Mark II regime (see section 3.2.1).

Stylized fact 3: High innovativeness

A high pressure to innovate characterizes the DIB. Maintaining a cutting edge knowledge base is important to be able to compete and export. For this reason there is a very high share of firms with R&D activities and as the economic figures showed, substantial amounts of money go into

R&D. Doing innovation is affiliated with much uncertainty and there can be a long lag between R&D and successful market commercialization (Lichtenberg 2007; Mowery 2010). Another insight into the R&D activity is that much of the R&D is publicly funded, or costumer financed. This is normal due to high costs and strategic importance to national security. Collaboration within the military-industrial-political complex like between firms in the defence industry and public research institutes as FFI is common. The Norwegian DIB could be viewed as a science-based sector (Pavitt 1984).

Stylized fact 4: High export propensity

The share of firms who are exporting (export propensity) is high in the Norwegian DIB. In many other manufacturing sectors the distribution of exporting firms is skewed with only a few large firms able to export (see section 3.5). In the defence industry both large producers and smaller specialized suppliers compete in international markets and export. The success is not so much due to the price they set, but the quality of the products and degree of technical sophistication (Castellacci and Fevolden 2011).

Stylized fact 5: Active public involvement

The Norwegian government is actively involved the DIB and they both constitute important parts of the military-industrial-political complex. For reasons of strategic importance to national defence the government seeks an active involvement through DIB framework conditions, regulation of offsets, export control, public R&D finance and procurement strategies. These strategies represent a stable demand for products which are important to the defence industry.

Stylized fact 6: Towards restructuring, consolidation and liberalization

The past couple of decades have seen a need for the DIB in Europe to consolidate with decreasing defence budgets. The military-industrial-political complex has taken the consequence of this and has been, and still is in a phase of restructuring. This restructuring aims at cost reductions through greater cooperation, mergers and acquisitions. In relation to this process the EU has launched its EU Directive 2009/81/EC which introduces a market liberalization mechanism with competition as an important policy tool (Edwards 2011; Guay and Callum 2002).

2.6 Research question

Based on the presentation of the military-industrial-political complex given here and the academic setting for the thesis, emerges two related research questions. The aim of this thesis is to answer the following questions:

1. How does firms' innovative capability affect export performance in the Norwegian defence industrial base with the current offset market structure?

2. With the EU Directive 2009/81/EC there will be a change in public procurement policy and market conditions. Different policy scenarios are possible. How will the change in policy and market environment affect the relationship between firms' innovative capability and export performance?

3 Theoretical framework

In this chapter, the theoretical framework for this thesis will be presented. A line will be drawn from the descriptive sectoral innovation system (SIS) theory, through the dynamics of evolutionary economy to current mainstream ideas on innovation, productivity and export. The aim of this chapter is to see these theories in context of each other, and to present the foundation for a model of the military-industrial-political complex. SIS is a useful descriptive framework, but the analytical value of evolutionary economics allows the framework to be used in both a quantitative and qualitative manner. Ideas from mainstream economics are also needed to explain who becomes an exporter, since this is an integral part of the research question. In any case, there is done very little research on the military-industrial-political complex in general and almost none from a SIS perspective with the added strength of evolutionary economics. As such, the thesis should present a substantial contribution to the field of innovation and SIS.

3.1 Systems of innovation

In his introduction to perspectives on innovation systems Edquist, defines a SI as

"all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations" (Edquist 2005, p.183)

There are several types of SIs, notably national, regional and sectoral (NIS, RIS, and SIS). In addition, there is also the technological innovation system (TIS). A NIS focuses on the national level and puts the innovation system into this context. Important contributors to this literature are Freeman, Lundvall and Nelson. The RIS focuses on a region, where a region could be anything from the size of a small county to encompass much larger geographical areas. The perspective is especially on the importance of geography. An important contributor to the RIS theory is Cooke (Cooke 2004). The SIS takes a sectoral view of innovation. Franco Malerba is important in this context. The SIS will be further introduced later. Finally, TIS as a concept was developed in a large part by Bo Carlsson (Carlsson 1995). The TIS concentrates on the use and diffusion of one or more technologies which transcends regions, nations or sectors. The focus is on how knowledge and competence flow and how they are transferred within the system. Where NIS, RIS, and SIS are more historic and static in their description of structural changes in the system, the TIS thoroughly explores the dynamic processes of change within the system. Bergek et al. has a good review with a helpful toolbox for analysis used in TIS (Bergek et al. 2008).

3.2 Sectoral innovation system

The SIS provides parts of the theoretical framework for this thesis. After a detailed preface it is now time to provide an independent and comprehensive review of this theory. Most of what is accounted for here is a compilation of texts by Malerba (Malerba 2002, 2005). The SIS deals with one sector and its products. How the sector is defined and the constitutive elements are described is specific to each sector. In other words, it depends on what your field of study is. Here it is the defence industrial base.

The theoretical basis for SIS is found in several traditions: Links and interdependencies (Dahmén, Carlsson, and Henriksson 1991), the SI approach (Edquist 2005) and the evolutionary theory (Metcalfe 1998; Nelson and Winter 1982). Malerba defines SIS as

"a set of activities that are unified by some linked product groups for a given or emerging demand and which share some common knowledge." (Malerba 2005, p.385)

The goal here is to present SIS for use as an analytical tool as well as a theoretical framework. In the following SIS will be presented in a tool perspective. A SIS consists of three main dimensions: Knowledge and technological domain, actors and networks, and institutions (Malerba 2005, p.385). The outline of the Norwegian military-industrial-political complex followed these three dimensions.

3.2.1 Knowledge and technological domain

At least two general knowledge domains can be identified: The field of science at the base of innovative activities in the sector and the domain of users and demand for sectoral products. How the knowledge in a sector is distributed and diffused in sector has a lot to say for the structure of the sector. If the knowledge is highly cumulative, and advanced integration capabilities are necessary, both of these conditions of themselves leads to a high concentration of firms in the sector. This is symptomatic for a Schumpeter Mark II regime (see section 3.4.2) with a high barrier to entry for new firms. This is the case for our object of study as presented in the previous chapter.

A Mark I regime is characterized by low appropriability, easy entrance, many small firms and low cumulativeness. A Mark I regime can turn into a Mark II regime with time. However, a disruptive technology could take a Mark II regime back to a Mark I regime. The boundaries of a sector are not rigid and set. On the contrary they are fluid and dependent on the transformation of knowledge. The boundaries could change fast. The flow of knowledge could be understood in light of the development block theory of Dahmén (1991).

3.2.2 Actors and networks

In a SIS the system is built up of networks with a web of relationships between actors. Actors (or agents) could be firms, subunits of firms, users and non-firm organizations. Firms and producers of products are key actors. Examples of non-firm organizations could be universities, government agencies, financial institutions and research institutes. In our case the dynamics between government agencies and firms in the DIB are of special interest. Looking at the heterogeneity of agents is important in relation to type of knowledge bases, competencies and behavior. This is a major source of differences between sectors.

3.2.3 Institutions

Institutions are defined as sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organizations. They are the rules of the game (Edquist 2005, p.182). Some institutions are sectoral while others are more nationally specific. Thus, sectors spanning over more than one nation (or technology) could contain more than one set of institutions dealing with the same matter. According to Malerba not much research has been done on the impact of institutions in SIS (Malerba 2002, p.257). In this thesis the institutions of the military-industrial-political complex is described through the government defence policies and firms' rules of behavior.

3.3 The propriety of SI and SIS as a descriptive framework

The goal of the thesis is to do an analysis of the Norwegian defence sector. A brief look at the way the industry behaves, leads one to believe it follows a pattern described in SIS. Looking at the military-industrial-political complex as a sectoral innovation system fits nicely with the theory. It contains a knowledge base. There are firms and government agencies which could be seen as actors. There are definitely relations between these actors, in effect a network. Finally, the defence industry has many rules, or institutions, some which are nation specific to industries, but also those that are sector specific (see stylized fact 5). It seems justified to apply the terms from SIS to the defence industry.

The SI approaches have some distinct strength as theory. Foremost it focuses on innovation and knowledge as endogenous variables explaining economic growth in industries. It follows the neo-Schumpeterian school of economics rather than the neo-classical. Following the evolutionary perspective gives a complex, but more realistic view of industry dynamics. Other points worth noting are how non-linearity and interdependency in the system are treated as part of the theory. Finally the role of institutions is also part of the framework (see stylized fact 5).

SIS enables description of the military-industrial-political complex to be performed in such a way as to identify dimensions not working properly in the sector. In other words, an analysis based on the descriptive SIS framework can discover system failures and elements responsible for such failures. This provides measures to determine policy implications and subsequently counsel to decision makers. The book 'Genesis of Innovation' recommends innovation systems as a good way to approach research on the defence industrial base (Laperche, Uzunidis, and Von Tunzelmann 2008). All of the above mentioned points are considered strong sides of the SI approach. Together they provide a good case for using the SI approaches to describe the defence industry.

However, there are weak points which must be addressed as well. The framework is descriptive with a strong historic component. There is no analytical component. Relationships between variables are not researched and analyzed. SIS provides qualitative insights and the model makes use of these. This is useful, but we need an analytical quantitative aspect. For this reason a section on evolutionary economic theory and the relationship between innovation and export is added as well, in order to create an analytically tractable framework.

3.4 Evolutionary economic theory

The model which will be presented in chapter five derives its structural framework from the SIS literature. However, the dynamics and inner workings of it are based on evolutionary economic theory.

"In a nutshell, evolutionary economic theory explains growth in terms of the dynamic interaction among heterogeneity, competition, selection and innovation, where the last leads to renewed heterogeneity and thus perpetuates the growth process." (Castellacci 2011, p.96) Since evolutionary economics is such an important part of the model, it is presented here and the stylized facts of the defence industry linked to the relevant parts.

3.4.1 Schumpeter

Schumpeter wanted to find ways of explaining economic change in terms of internal and not external factors. He had

"a vision of economic evolution as a distinct process generated by the economic system itself." (Schumpeter 1937, p.166)

According to his theory, firms that manage to innovate would be rewarded by a better competitive position and increased profits. In other words, the evolution of the economy is driven by firms getting a competitive edge through innovation and not through competing on product price. Even in the presence of a concentrated industry with large firms, technological competition between firms will drive the evolution of the economy (Fagerberg 2003) (See stylized fact 2). This thinking was novel in his time and an important contribution to later theories to come.

3.4.2 Nelson and Winter

Based on the thinking by Schumpeter, Nelson and Winter developed a model to study economic development. In the model they set up a set of heterogeneous agents (see stylized fact 1) with bounded rationality and behavior based on satisfactory conditions. This means that one firm is not representative for the whole population, they are all different, and they do not have the complete overview to behave perfectly. Mark Knell (2008) state that heterogeneity was not a new historical concept, but that the novelty lied within concepts of none-representativeness and population thinking. Agents have to take action based on incomplete information and the result is uncertain. The rules of action called 'satisficing behavior' states that the action is not necessary optimal, but it is satisfactory. The profitability is an important issue in the model pertaining to the 'satisficing behavior'. It determines the decisions to invest in technological activities. The search into technological activities could take two paths; either into innovation, or imitation. This is a key feature of the model in this thesis to be presented. Nelson and Winter presents a technological regime called the cumulative technology regime. Here, the growth of productivity is seen as an endogenous parameter determined by innovation based on the firm's technological capabilities. This is related to two different regimes (Schumpeter Mark I and Mark II) described by Schumpeter. See Dosi (1995), Clausen (2004), Malerba and Orsenigo (1996) for an introduction to the Schumpeter Mark I/II and technological regimes.

Two key results emerge from the model of Nelson and Winter: Firstly, more innovation leads to a more rapid growth of productivity. Secondly, more imitation leads to a less concentrated and thus more homogenous market. These results should be kept in mind for the analysis to be presented later. For a more complete overview on the Nelson and Winter model see '*An evolutionary theory of economic change*' (Nelson and Winter 1982) or a summary by Castellacci (2011).

Since the work of Nelson and Winter, many others have further developed their ideas creating varying evolutionary economic growth models of routine-guided heterogeneous firms (Castellacci 2011, p.94). Among later additions is the notion of 'learning by doing' by Poussas which is incorporated into the model presented in this thesis (Fagerberg 2003, p.148). These models have some similarities with mainstream models of heterogeneity, growth and competitiveness (Castellacci 2007).

3.5 Inspiration from mainstream models: R&D, productivity and export

Most of the evolutionary economic literature has so far focused on the impact of innovation on productivity growth. There is not much literature studying the relation between innovation and export. This relation is vital in this thesis. For this reason it is important to draw inspiration from some of the recent mainstream economic literature on innovation and export in order to fill the gap.

Melitz(2003) is the seminal paper of a new strand of research on firm heterogeneity and international trade. His model studies the relationship between firm productivity and the ability to export. From his model stems the notion that firms which performs above a certain profit threshold has the capacity to be exporters. Firms which are successful manage to cover the costs of entering into competition on foreign markets. For this reason, firms that perform above a certain profit threshold could be considered exporters. Firms which are not productive enough do not have the resources to enter into foreign markets (Melitz 2003). Another point in Melitz model is the impact of trade liberalization. To tackle foreign competition, firms must become more productive. These firms demand more labor, which in turn induce higher wages. This demands a higher profit to cover the costs of more expensive labor. Faced with stronger competition the more productive domestic firms must increase profit to stay in the market (Castellacci 2011, p.101).

The link between firm productivity and ability to export in Melitz' model has been demonstrated. The same also apply to the link between a firm's innovative activities (R&D intensity) and performance in international markets. See the overview presented by Castellacci (2010) for an overview of relevant articles demonstrating these linkages.

All of these aspects are important in the model presented by this thesis. Key characteristics of the model is to simulate foreign competition through an increased profit target, study the share of exporting firms (export propensity) and to link firms innovative activities with the export performance (see stylized fact 4).The methodology of the model is what makes the dynamics of evolutionary economics analytically tractable. The next chapter presents the methodology of ABMS and how the military-industrial-political complex model contributes to the literature of evolutionary economics.

4 The methodology of agent-based models

4.1 An introduction to computational models

Agent-based model simulation (ABMS) belongs to the world of computer simulation and is an integral part of this thesis. A computer simulation is a program that is designed to model something. Let the program run and watch the simulation unfold. It could be a physical phenomenon like gravity, where you define a physical space, launch a ball and see how far it goes under the influence of gravity. In simulations like these, you would have a good understanding of what you model. The results of the simulation should not be surprising, after all everyone has experience with gravity and how it works. Many times however, you can find yourself dealing with phenomena where you know some basic rules, properties and behavior, but cannot predict the future outcomes. The variables are too many, the equations too complex or the behavior is not possible to express in a tractable mathematical manner. These are considered complex models and it is here computers come to our aid. The power of computer simulations is in the computer's ability to process vast amounts of data. Computers are capable of tackling many variables, complex equations and multiple events happening at the same time all affecting each other. With computer simulation you have a tool to study complex systems, behavior and phenomena. This is the beauty of computational modeling.

Computers have been used for simulation purposes since World War II. Several different types of models have emerged over the years. Models developed for engineering purposes was developed early. However, models for simulating social phenomena like economic development were also constructed. In the beginning the emphasis was on macro modeling. Find one equation which explained the whole system and make the computer tell us the results. This has limited application since it is hard to find such equations. At best they were often good approximations. Later in the seventies and eighties models emphasized the micro perspective where many tiny events together told a larger picture. However, the big picture was only the sum of all its pieces.

There was no interaction on the micro-level and the models were still in this sense static. Then in the nineties models which looked at the micro-macro picture was developed. Here, interactions at the micro-level influenced the macro-level and vice versa in a dynamic way (Macy and Willer 2002). This is the type of model which characterizes an agent-based model.

Today computer simulations have indefinite use in all sciences. The approach of agent-based model simulation has its historical roots in applications like Artificial Intelligence and Complex Adaptive Systems (North and Macal 2007). It is an analytical framework well suited to investigate heterogeneity and complexity as a part of physical, biological and social systems. In the past ten years it has also found applications within the socio-economic field, mainly computational and evolutionary economics (Dosi, Fagiolo, and Roventini 2010; Pyka and Fagiolo 2007; Tesfatsion 2002). For an illustrative example of an agent-based sociological model, imagine a flock of birds flying in V-form. When trying to describe it with mathematical equations it is impossibly hard to model. There is no leader bird telling the rest how to form up. If you instead look at each individual bird like an agent with 3 simple behavioral rules it becomes simpler. Make a system where each bird is told to: 1. Don't come to close to your neighbor. 2. Match the other birds' airspeed and altitude. 3. Head for the perceived center of the flock. Out of these three simple rules the V-formation suddenly emerges in a simulation. This is an example of a simple, but powerful agent-based model. Today agent-based models see applications in a wide variety of fields like history, sociology, biology, business management and economy. The methodology of ABMS share similar traits with simulation techniques called system/industrial dynamics and discrete-event simulation (Macal and North 2010). The aim here is not to elaborate on the distinguishing differences, but the clue lies in the focus on agents and emerging behavior which is characteristic of agent-based modeling.

4.2 Agent-based modeling and innovation

There has been an increasing interest in agent-based modeling in the field of innovation and then especially evolutionary economics. Authors like Tesfatsion, Fagiolo and Pyka have strongly advocated the use of these models (Pyka and Fagiolo 2007; Tesfatsion 2001). In fact Pyka writes: ABMS "(…) is "the" modeling approach to be pursued in evolutionary settings." (Pyka and Fagiolo 2007, p.8)

Why is that? Four reasons are presented by Pyka in his presentation of ABMS in evolutionary economics cited above. One advantage is the ability to show how collective phenomena come about through the interaction between autonomous and heterogeneous agents. It focuses on more than just quantitative change in the system and gives access to studying qualitative change as well. Secondly, it enables the developer to use the model as a computational laboratory exploring different potential paths of development and institutional arrangements. By doing this, it allows for guidance and assistance to be given to firms or policy makers in their particular contexts. Thirdly, the approach is a bottom-up way of modeling the system with an emerging collective phenomena and top-down influence of institutional settings on individual agents' behavior (Tesfatsion 2002). The fourth and last reason is the power which lies in working with computational models. Increasing complexity in programming languages and increasing availability of computing power enables economists to model in more and more realistic detail.

There are several different terms related to ABMS and evolutionary economics. Evolutionary economics, agent-based computational economics (ACE), neo-Schumpeterian models and history-friendly models are just some of them which share many similar traits.

4.3 Agent-based modeling explained

An agent-based model is built up around agents. Each agent is an entity, like a person or a firm. In this thesis the agents are defence firms. These agents are heterogeneous in the sense that they have differing characteristics. The agents interact amongst themselves and with an environment.

The interaction with other agents and the environment can change the agent, other agents or the environment itself.

Each agent is equipped with a set of rules for how it is supposed to behave. These rules are often identical for each agent, unless there are several subgroups of different types of agents in the model. They are usually quite simple rules as with the example of the bird flock, but could be very sophisticated and advanced as well. In other words, the model regulates micro behavior and rules of interaction. Out of this emerges a macro picture. It is possible to make these models deterministic, but also uncertain and unpredictable by introducing variety and random elements. The interesting feature of an agent-based model is that the macro picture emerges as something more than an aggregation of all the agents. It is a bottom-up approach where the whole is bigger than the sum of its parts. It is not possible to explain the macro picture based on one agent, it emerges through the micro behavior over time.

4.3.1 Structure of an agent-based model

According to Macal and North (2010) an agent-based model has three elements:
1. A set of agents, their attributes and behaviors.

2. A set of agent relationships and methods of interaction: An underlying topology of connectedness defines how and with whom agents interact.

3. The agents' environment: Agents interact with their environment in addition to other agents.

In order to create an agent-based model a developer must look at what he is modeling and identify the above mentioned aspects and model it. In order to do this he needs a computational engine, a software environment. This software should be an agent-based modeling toolkit based on a preferably object oriented program language (Netlogo is used in this thesis). In this environment the developer creates a program. When you run the program you allow the agents to repeatedly execute their behaviors and interactions. Thus you have a simulation. This simulation is often time-dependent and operates over a timeline with time-steps.

4.3.2 The autonomous agent

A key defining characteristic of agent-based modeling is the agents' capability to act independently. Defence firms are endowed with behavior which makes them act on their own, according to their own set of goals. The agents are active instead of passive, reacting to other agents and the environment. An agent is self-contained and uniquely identifiable as an individual with clearly defined boundaries. It has features which make it distinguishable and recognizable to other agents. It could easily be set up to exert a bounded rationality. In addition, the agent is autonomous and self-directed. It can sense information through interacting with other agents and the environment, and relate this to the behavioral rules in order to make its own decisions. Another important aspect is that the agent is characterized by a certain state which varies over time. This state represents values of essential variables related to its present situation or attributes of the agent. The state of the agent-based model is an aggregation of all the states of the different agents. Each individual agent's behavior is dependent on its state, so the more possible states, the more advanced could its behavior be.

Other useful characteristics of an agent include the feature of being social (interacting with other agents) or being adaptive. It could have rules for changing its state by having the ability to learn and change behavior based on accumulated experience. Lastly, agents may be heterogeneous. Random elements may be introduced in each agent like the amount of resources it has. Combined with a memory function, past interactions with other agents may have an effect on behavioral rules further differentiating each agent as they all have different experiences.

4.3.3 Interaction with other agents and the environment

An important tenet of agent-based modeling is that not all agents are interacting with all the other agents at the same time. Only local information is available to each agent. The system is decentralized with no central authority to publish global information, or to direct agent behavior towards a certain goal. Agents interact with a subset of other agents, and they all do it at the same time. The behavioral rules determine which other agents are considered local, and this could change rapidly over time as the simulation proceeds and agents change their individual states. In addition to social interaction with other agents, an agent could also interact with the environment. If it is placed in a physical space, it interacts with this space moving through it. Depending on where it is in space, different behavior could be deemed correct at the time. The agent could also be placed in the context of a market, which is the case in this thesis, where interaction with the environment is based on supply, demand, profit goals, competition and prices (Macal and North 2010).

4.4 How to build and use an ABMS for analysis

Faced with developing a specific model, three options present themselves. Either one begins with a small and simple model and keep making it progressively more complex, or start with an existing descriptive model and simplify it into a model, or take an existing model and modify it to your needs. From the next chapter it will be clear that here the last option was chosen. When you build a model it is vital to find some key stylized facts upon which you want to structure the model. These should guide how the model works and be reflected in the inner dynamics of the model.

An Agent-based model has certain constraints which influence the way analysis is done. In these models the quantitative aspects are often sacrificed at the expense of qualitative aspects. An agent-based model of an industry cannot predict the future in hard numbers; rather it can point into what directions it would move based on different environmental settings. By studying the emergent phenomena one can discern underlying patterns and learn what type of agents, or what type of rules, which drives the evolution of the population. In order to arrive at these answers, four different steps must be done during the analysis.

To be able to work with a model, one first needs to get familiar with it and explore it. This requires of course a good insight into the code of the model, but also that you play with all the different parameters in the initial conditions for the agents and environment. This is also known as exploring the long-run properties of the model, where you explore the effect of one parameter for all its values on the rest of the model. If a variable takes values from 0 – 10 on a continuous scale, you run the simulation with for example 200 different values of this variable within the parameter space 0 – 10. Looking at the end results of the simulation you get an idea of how this variable affects the simulation. This should be done for all variables thought to be important in influencing the behavior which you want to study in the model.

Secondly, when this exploration of the model is performed you need to calibrate it, especially if there is a need to study the model in a specific context. In order to do this you use your knowledge of the long-run properties to calibrate the model so that the initial conditions and expected behavior resembles the situation you want to study. The calibration can only be done with a thorough knowledge of the model code and behavior related to different parameter settings, which you identify from the long-run properties. These analyses also require that you set up a method for data collection. The data must be able to be processed either statistically, graphically or both. To do that you need to program the model in such a way that it collects data on the different states of all the agents and the environment for you. Then you need an additional program to treat the data like Stata, R, Excel or similar.

Thirdly, agent-based models based on principles of evolutionary economics are in their nature uncertain and stochastic, or non-deterministic. This means that when you want to study outcomes of your simulations it is often useful to set up a Monte Carlo distribution where you average your results from several runs into one value. The less variance and runs you need to get stable output of data, the better. Many converging results based on random elements means the model is rigid and that the emerging phenomena are easier to identify. This is good for further analysis.

At the fourth and final step you have analyzed the properties of the model, calibrated it to your context of study and taken into account the random nature of your results. Now is the time to start the statistical or graphical analysis to determine emergent behavior. The quantitative results are uncertain, but the more the model is based on real data, the more accurate the quantitative data tend to be. However, the strength of an agent-based model lies in the ability to portray qualitative change. For this reason quantitative results should be interpreted in a qualitative sense, as a direction of change. This direction of change needs to be identified by analyzing the data and explained through the underlying behavioral mechanisms of the model. To explain results of a simulation can be very difficult since most of the dynamics are endogenous and there could be many parameters and rules of interaction which in relation to each other influence the results of the simulation.

4.5 Advantages and disadvantages of ABMS

As outlined above there are some strong linkages between innovation, and particularly evolutionary economics, and agent-based modeling. By now many of the advantages of this methodology should be clear: The interesting features which could be achieved with an agent-based model are the ability to model processes of innovation, imitation and competition as endogenous interactions. It allows for different market structures, changing R&D intensity, network creation, changing levels of imitation and cooperation, boundedly rational agents (trying by trial and error), radical and incremental innovations, variety and selection through entry and exit, long run "lock in" properties, heterogeneous agents within a population of firms, and the possibility to model the influence of public policies. Lastly innovation could be based on 'satisficing behavioral' rules in this modeling approach.

However, there are some drawbacks of this methodology. In the field of innovation it is still a quite new approach. Many articles using agent-based modeling start by explaining their methodology and do not take for granted the reader necessarily knows what ABMS is. As a consequence, researchers are still not in total accord on all the definitions, and various names on very similar types of agent-based models flourish in the academic literature. For example most researchers agree on the most important properties of an agent, but there is no unilateral definition of what an agent is yet. This type of variety gives ground for a broad approach to the use of ABMS in innovation studies, but at the same time it is hard to compare different models on the same topic, since they are not directly comparable and developed under different frameworks. Another possible shortcoming of these types of models is their inability to make accurate qualitative predictions due to rules of uncertainty and the fact that most models are still quite stylized. As of yet, many innovation agent-based models are aimed at reproducing one or more qualitative stylized facts, but few have yet explored the possibility to build 'what-if' scenarios to analyze policy implications for decision makers. This is hopefully something which will be done more in the future since the study of qualitative change is a strong feature in these types of models. The model developed in this thesis is such a model which takes advantage of the strong qualitative prediction feature in order to build 'what-if' scenarios and present policy implications based on these scenario outcomes.

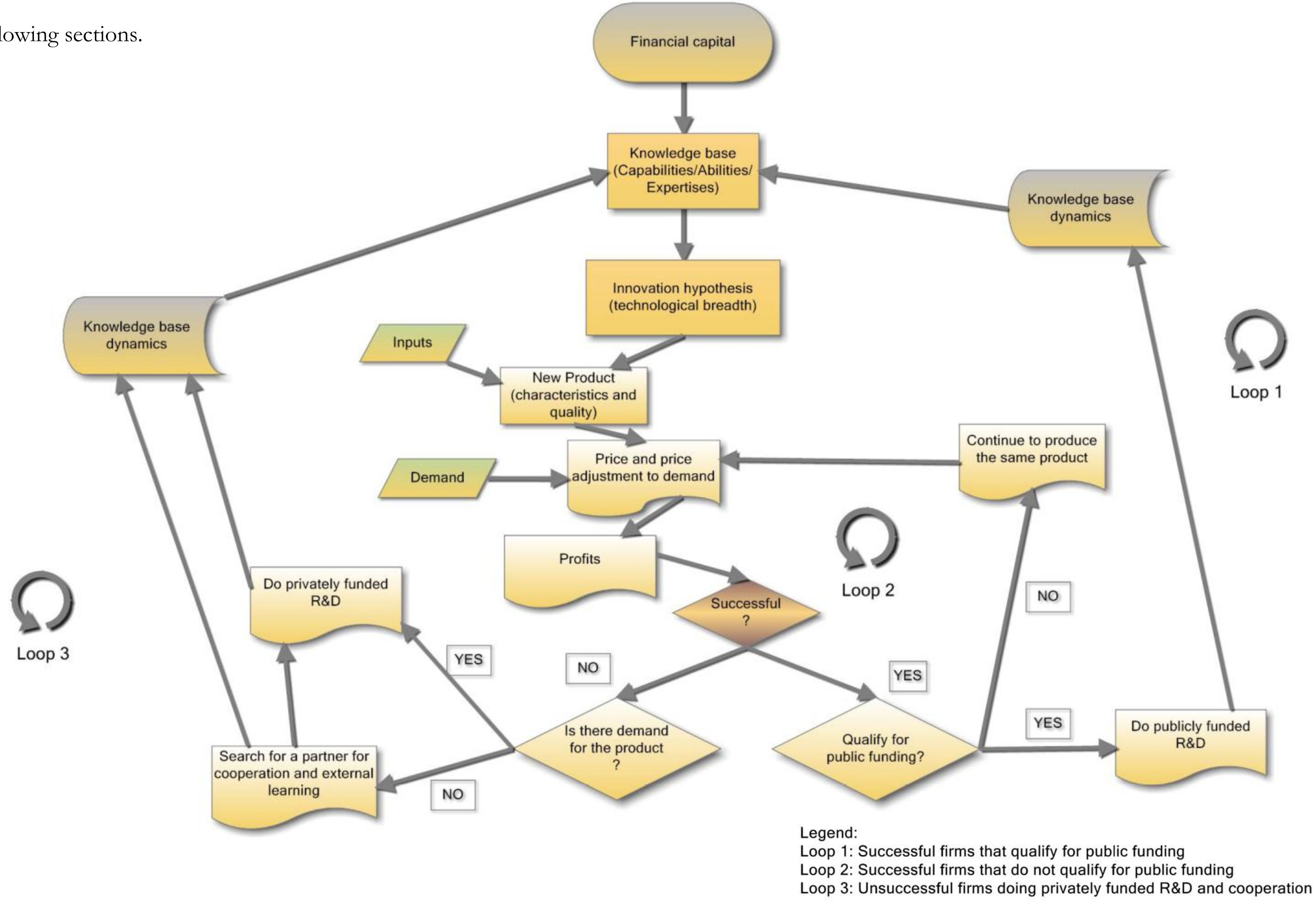
All in all the advantages of agent-based modeling makes it an attractive methodology to help answer the research questions in this thesis, despite some shortcomings of the methodology.

5 An ABMS model of the Norwegian military-industrial-political complex

5.1 Introduction

This chapter describes how the model of the Norwegian military-industrial-political complex works. Based on our knowledge of the military-industrial-political complex introduced in chapter 2, and the theoretical framework provided along with the methodology, it is now time to introduce the novel simulation model of the military-industrial-political complex. The model was developed in a software environment called NetLogo. This software is used to program agent-based models and is based on a simplified object oriented computer language. The developed model is based on the SKIN model (Simulating Knowledge Dynamics in Innovation Networks), introduced in a number of papers by Gilbert et alia (2007), Pyka et alia (2007) and Ahrweiler et alia (2011). This is a generic agent-based model that provides a good analysis of firms' interactions based on innovation, learning and knowledge dynamics in knowledge intensive industries. The models theoretical framework is taken from theory on innovation systems and evolutionary economics, and as such is a close match to the type of model needed here. The SKIN model is well analyzed and already used to provide policy implications for other industry sectors in the EU. The defence industry has its own very idiosyncratic features and the SKIN model has to be developed further to be used in this context. For this reason the model presented here is an extension of the SKIN model introducing the public agent as the political dimension and a special focus on export. In the following sections the structure and calibration of the model is presented, starting with figure 1 (below) which explains how one firm behaves in any given time period t.

Figure 1 Figure 1 is a flowchart which describes the behavior of an agent (private defence firm) in any given period t. It will be explained in the following sections.



5.2 Structure and calibration

5.2.1 Agents

Along the lines of the methodology presented in the last chapter, defence firms (producers of defence products) are the agents on a micro-level in this model. They are the ones who perform all the actions and are responsible for the dynamics in the model. Based on the stylized fact 1 (heterogeneity) they all have different characteristics. Besides from varying initial capital (large firms co-exist with SMBs in the market), the most important distinguishing feature is their knowledge base. The notion of a knowledge base is here taken from the theory on sectoral innovation systems (see section 3.2). Each firm's knowledge base, or technological capital, is represented as a series of vectors. Each vector is a unit composed of three elements:

- **Capability (C):** The capability represents a technological domain within the defence industry comparable to the EDA taxonomy mentioned in chapter 2. The capability is a knowledge area, for example 'secure computing techniques'. In this model there are 1000 different capabilities defined.
- **Ability (A):** The ability is more competence related and defines the ability to perform a certain application in this area of knowledge. Here it is represented as an integer between 1(low) and 10 (high).
- **Expertise (E):** The expertise is an indication of how well the firm masters this ability. It is defined as an integer between 1 (low) and 10 (high).

A firm can have several capabilities, each with its own vector (C/A/E). All these vectors combined constitute its knowledge base.

The defence industrial base is characterized by a high degree of innovation following stylized fact 3. The model assumes firms use and tries to improve their knowledge base in order to produce a better product which meets their profit target. The product is made on the basis of some of the vectors in the knowledge base. These make up what is called the Innovation Hypothesis (IH).

The product is a function of the capabilities and abilities employed in the product. Accordingly the product is characterized by the breadth of competence put into it. In other words; how advanced it is. The quality of the product is characterized by the abilities and expertise in the IH and this is a measure of the depth or specialization. Capabilities in the IH which are used several times, gain a higher expertise level (learning by doing, see section 3.4.2 for SIS theoretical background). Capabilities in the knowledge base which are not included in the IH, loose expertise and are eventually forgotten.

5.2.2 Market environment

The market environment is a simulation of the Norwegian domestic defence market. There is no foreign market in the model, but according to the theory on the relation between productivity and export by Melitz (see section 3.5); firms are regarded as exporters when their profit exceeds a certain threshold. Competition from foreign firms in the market is regulated by the *success threshold* (to be explained later) also according to Melitz' theory. The firms operate in a market split into two parts according to different demand patterns. One part of the market is between firms where they make products which work as input to other firms products. In this market they compete on the basis of price and quality. A firm which cannot find the appropriate inputs to its own product to an affordable price will not go into production. The inputs a firm needs are dependent of the characteristics of the product and they find it by searching through other firms' products, prices and quality. In this market there are adjustment mechanisms for pricing the product. If there is much demand the price increases or vice versa.

The other market is products destined for end-users like the military. Here we assume indefinite demand in line with public procurement policy. Only products which firms know the government wants are produced and the price is based on the quality of the product. Further, it is assumed that if the profit of a firm is large enough, it is capable of exporting in line with the ideas on international trade by Melitz presented in chapter 3.

5.2.3 Research, imitation and public procurement policy

In the model, innovation is a driving force for the economic dynamics and linked with the market performance of a firm. If a firm is not happy with its performance according to an exogenously set *success-threshold* (explained later), it has two options: Either innovation by doing its own private incremental R&D, or innovation through cooperation (forming partnerships with other firms), which include external learning and elements of imitation. These strategies are associated with uncertainty, since the result is not necessarily positive, and this introduces another random element in the model. Private R&D is done when there is demand for the product, but the profit is too low. It works by adjusting the ability in one of the vectors of the IH. Cooperation is chosen as a strategy when there is no demand for the product and they need external knowledge from other successful firms. Cooperation works by adding a knowledge base vector from another firm into its own IH, but with a reduced expertise level. Firms will choose to do either incremental research or cooperation as long as their product does not meet the profit target which is the parameter *success-threshold*.

In addition to the defence firms, there is a public agent in the model. There are typically two public procurement strategies to be followed in order to allocate funds and instigate publically funded R&D. The public agent can grant funds to a successful firm on the basis of its product competence breadth (above a given *competence breadth threshold*). A high competence breadth (many capabilities used to develop a product) means the firm is a large company like Kongsberg or Nammo. This allocation strategy is often the case with how the Ministry of Defence chooses to allocate funds.

The public agent also has another possible procurement strategy. The public agent can grant funds to a successful firm where the product is characterized by a high quality (above a given *product quality threshold*). This corresponds to a smaller more specialized firm (SMB) with a narrow competence base. Innovation Norway is a typical public agent which utilizes this type of allocation strategy.

By applying for public innovation funding, the firm enters into a cumulative virtuous circle, since it is likely to increase its profits and qualify for further public funding in the future. The basis of this cumulative regime is found in the theory on evolutionary economics by Nelson and Winter (see section 3.4.2). This feature is introduced to emulate the effect of offsets and the current public procurement strategies. The offset mechanism is complex to simulate, but this virtuous circle provides a good approximation.

To summarize the model (see figure 1), two key properties describe the model. On the one hand, in any period t, firms operate within three different groups (loops). Loop 1 characterizes firms which are successful innovators that qualify for public funding. Loop 2 characterizes firms that successfully manage to innovate and sell their products, but do not qualify for public funding. Loop 3 characterizes firms that are unsuccessful performers and that engage in either private R&D or imitation by cooperation. Secondly, there are two different cumulative causation mechanisms. One where good performers get access to public funding and further strengthen their position in the market, and another catch-up mechanism where bad performers have the chance to improve their performance through private innovation. The theoretical foundation for how innovation can drive the economic dynamics in the defence industry is found in section 3.4 on evolutionary economics.

5.2.4 Calibration

The model is carefully calibrated to simulate the Norwegian defence industrial base, emphasizing firm behavior, knowledge base, the particular institutions of the defence sector and public involvement. The number of firms is 150, which is close to the 120 current firms, with a few large and many small firms. The market is regulated to have the same concentration index (explained below), and the rate of R&D and cooperation is also tuned to fit patterns of the

Norwegian defence industry. The profit level for which firms are considered exporters is also calibrated to fit the number of exporters in the defence industry (see section 3.5) which is at about 38% at present. In sum, the model is made to simulate the Norwegian military-industrial-political complex with its idiosyncrasies as a Schumpeter Mark II regime (see stylized fact 2) based on the theory presented in chapter 3.[1]

Key explanatory environmental and policy variables in the model

There are four main explanatory environmental and policy variables in the model which characterizes the economic environment and could be affected by public policies and strategies over time.

Cooperation propensity: This defines the extent to which firms are willing and able to engage in partnerships with each other. It ranges on a scale from 0.50 (no cooperation) to 0 (everyone cooperates).

Success threshold: This indicates the threshold for when firms are satisfied with their profit. Below they seek to innovate; above they sell their product or try to apply for public funding. The parameter is defined in the profit space from 0 to 12.000. It corresponds to the level of competition and productivity needed in the market. (See section 3.5 on the relationship between competition and productivity.)

Product quality threshold: This defines the quality of a product and is the first criterion for public funding. It ranges on a continuous scale from 0 (easy access to public funding) to 10 (difficult to get access to public funding).

Competence breadth threshold: This is the second criterion for public funding and describes how broad the competence base of product is. It ranges from 0 (specialized firms with narrow

[1] The knowledge base is not in itself calibrated to the defence industry, but is set up with random values and then evolves through each simulation. This should, however, not affect the emergent behavior under study, since the results are averaged by a Monte Carlo algorithm.

competence breadth have easy access) to 10 (it is difficult for specialized firms to get public funding).

Key aggregate (industry-level) outcome variables

The five following variables are aggregate outcome variables which describe the emergent properties which we study in the thesis. They are the result of micro-level interactions between firms and also the factors which we seek to explain.

Export propensity (%): Number of firms considered able to export as a share of total number of firms in the industry. This is an important variable for our analysis.

Concentration index: This is defined as the C5 concentration index which is the combined profit of the five most profit-earning firms divided by the total profit made in the market. In the Norwegian defence industry the C5 index is currently 0.75.

Mean product quality: This is an average of the product quality of all firms in the market.

New privately-funded R&D projects (%): Number of firms that do private R&D as a percentage of total number of firms.

New publicly-funded R&D projects (%): Number of firms that qualify for public funding as a percentage of total number of firms.

The analysis in chapter 6 use data from the model presented in this chapter to study how the dynamics of the explanatory environmental and policy variables shape long-run properties of the model. In addition, the analysis studies how different future scenarios and public policy may affect the relationship between innovative capabilities and future export in the defence industry (see stylized fact 6).

6 Simulation results and analysis

This chapter presents the analyses of the data produced by the model which has been developed. Three analyses are performed. The first study the long-run properties of the model. The second is a statistical analysis which substantiates the analysis of the long-run properties. The third analysis explores five possible future scenarios of the Norwegian defence industry and compares them to a possible trajectory of the current public procurement regime.

The model produces three types of data which is used for analysis. The first analysis outlines how the four explanatory environmental and policy variables of the model shape long-run properties of the model (see section 5.2.4). Data on the explanatory variables used for this analysis is Excel based and graphically interpreted. In addition, there is firm panel data (observations of all variables, for all firms and time periods) which is output in a format to suit a statistical processing program called Stata, which is employed in the second analysis. Section 2.2 refers to the third analysis of how different scenarios and public policy may affect future export and market opportunities in the defence industry (see stylized fact 6). Data on the aggregate outcome variables are Excel based and graphically interpreted. These results portray the development of the five aggregate outcome variables (see section 5.2.4).

In this chapter the long-run property analysis is performed with respect to each of the four explanatory environmental and policy variables. Secondly the statistical results are reviewed and used to further substantiate the results from the long-run properties analysis. Finally the chapter concludes by presenting an analysis of the current and the five possible future scenarios with their respective policy implications for defence public procurement strategies.

6.1 Exploring long-run properties of the model

To explore how the four explanatory variables shape long-run properties of the model, a series of simulations were done and data collected. Each explanatory variable is incremented by a small step 200 times, where it takes all possible values within its definition domain, resulting in 200 simulations. The end result after the simulation has run for 400 periods is collected for each aggregate variable in the 200 simulations. In each simulation the variables stabilize after 250 – 300 periods, so 400 periods is more than enough for the results to be stable. This results in spreadsheet data which is presented in charts. These charts describe the effect of the four explanatory environmental and policy variables on the five aggregate outcome variables. This adds up to a total of 20 different charts presented in the following sections.

6.1.1 Cooperation propensity

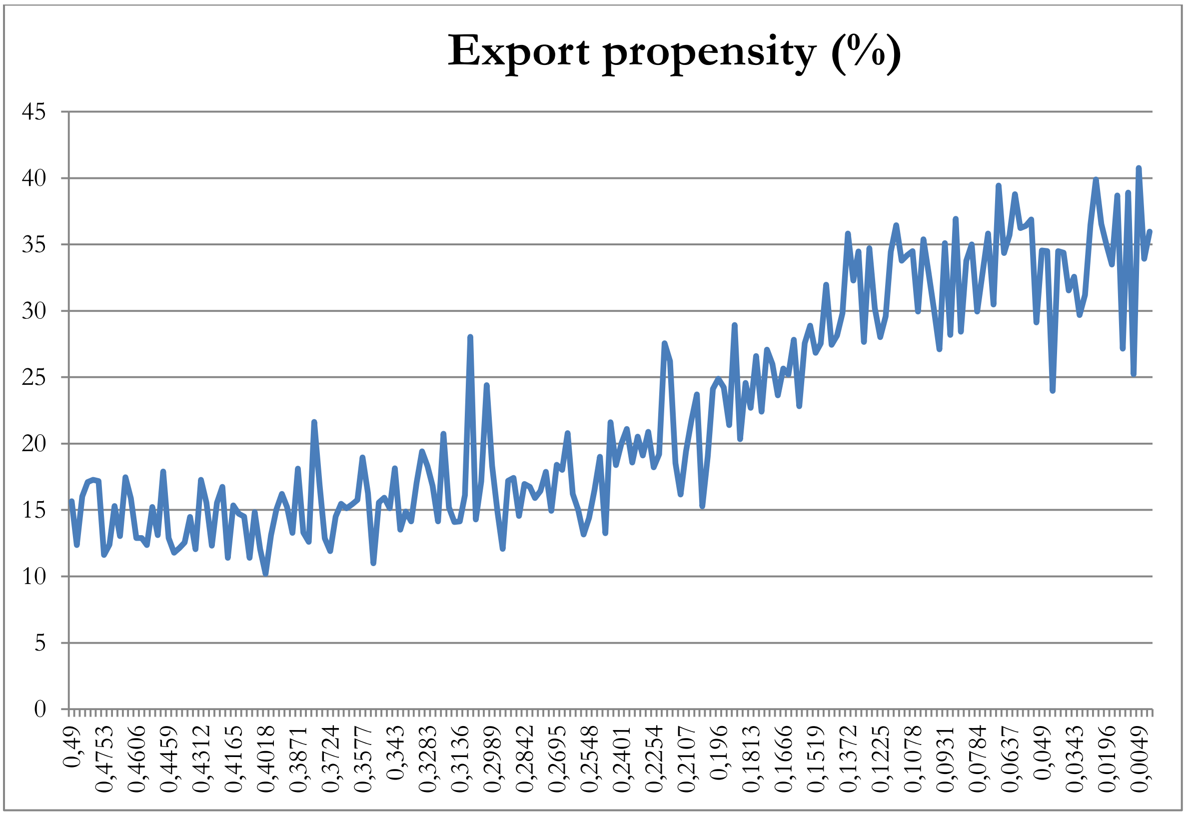
Result 1: Cooperation and export propensity are positively correlated.

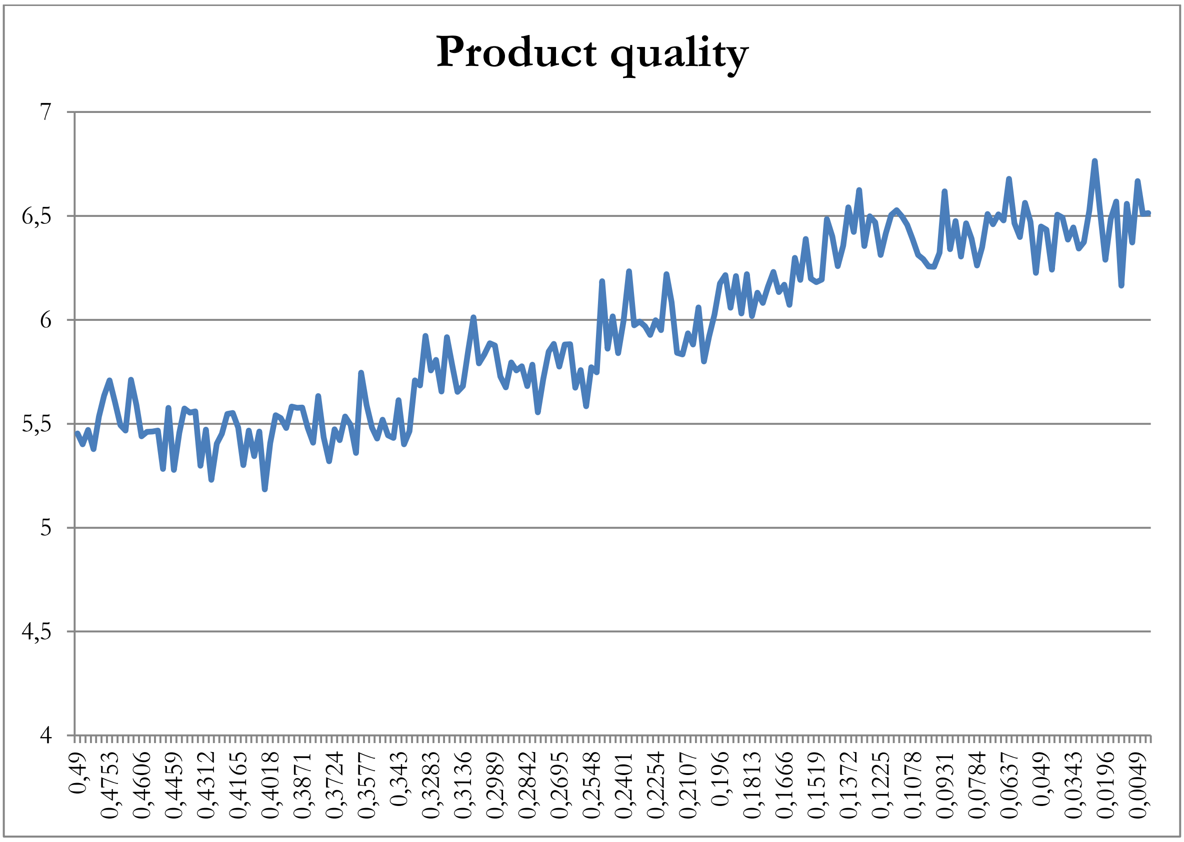
The first result is presented in figure 2 (below) with five charts. The cooperation propensity (to which degree firms can cooperate) is shown as a function of each of the five aggregate outcome variables. The final value of the aggregate outcome variable in each simulation is presented. The first chart in figure 2 shows this clear positive relationship between the cooperation and export propensity. When firms have a low cooperation propensity (0.50 – 0.30), they find it hard to form partnerships with other firms. Even if they are unsatisfied with their performance in the market and the strategy dictates that they should find a partner, it is difficult to find one. This means the level of imitation and knowledge spillover is limited. For this reason firms with unsatisfactory performance are prevented from catching up with the rest of the market. When firms have a high cooperation propensity (0.15 – 0), they easily find a partner if they wish to. The catch-up mechanism of imitation and knowledge spillover allow dissatisfied firms to become successful, and for this reason more firms are able to export, and the export propensity is increased. In terms of figure 1, when firms are more likely to cooperate, they are also more likely to move from loop 3 into loop 1 or 2.

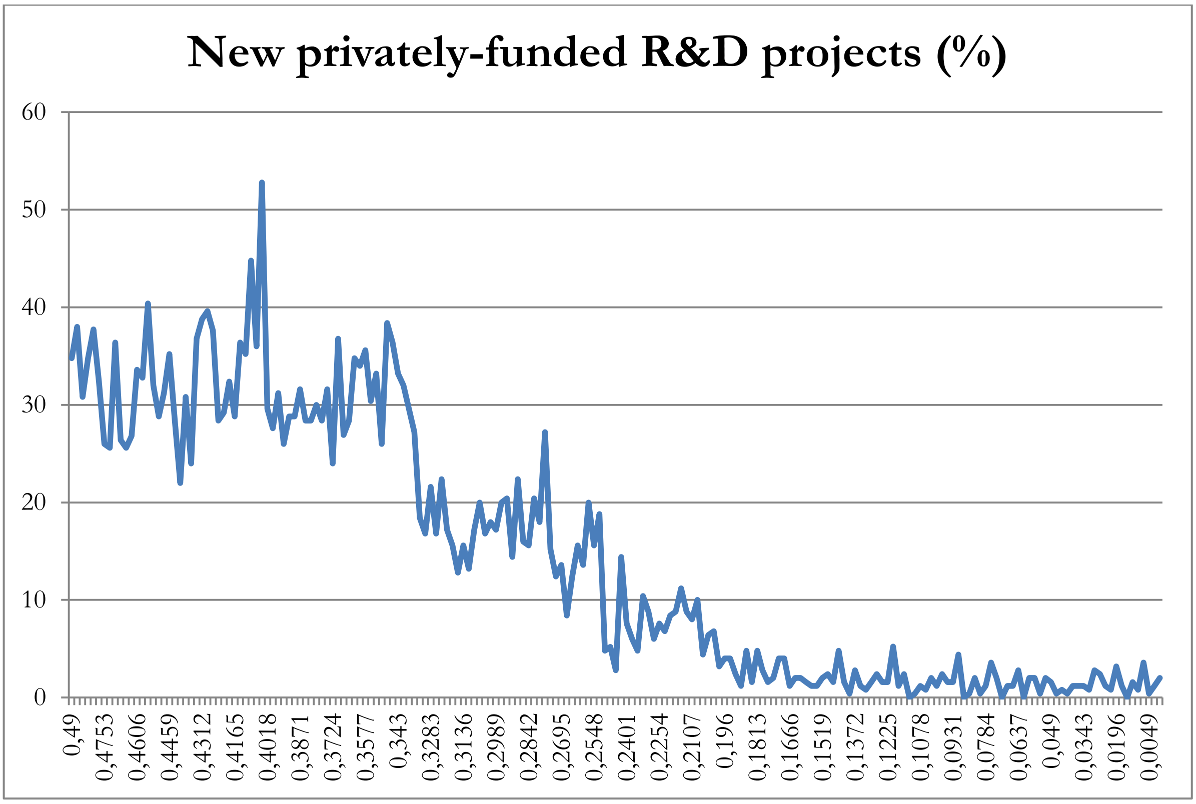
The four remaining charts support this result. The concentration index indicates that when firms cooperate more the market becomes more homogenous (see section 3.4.2), the profits more evenly distributed and the concentration decreases. With increasing cooperation the quality of products rises as an indirect effect of the need to improve newly acquired capabilities. Fewer firms have to do private R&D (since more escape loop 3) and more firms do public R&D since more of them qualify for public funding. This is in line with the intuition behind theory of evolutionary economics presented in chapter 3. Innovative capability is vital for good economic performance. If the opportunities for innovation are hampered, the economic performance is worse than what it could have been.

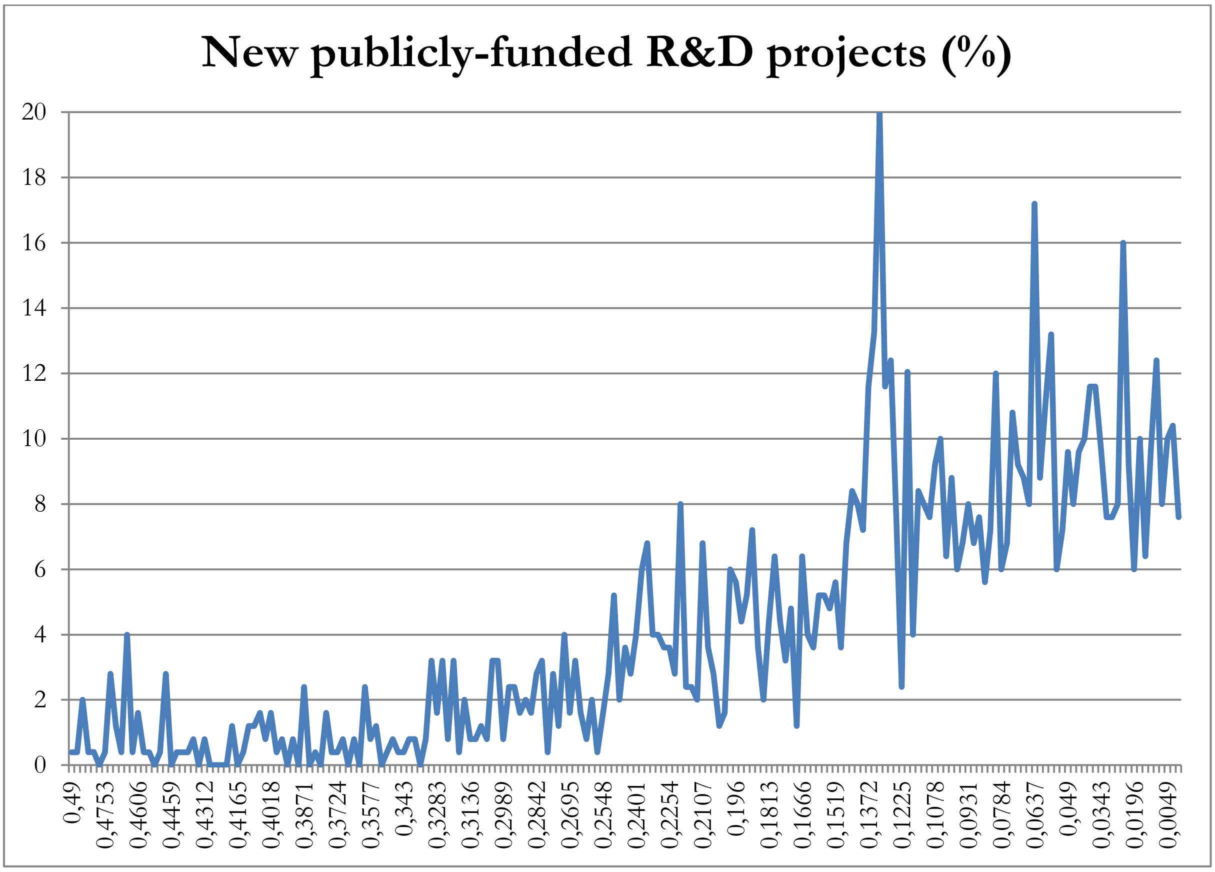
This result has an important policy interpretation and relevance. One of the intentions of the EU Directive is consolidation of firms. With a more open and integrated market firms would cooperate more and this points in the direction of the intended purpose. The result could be interpreted as an indication of what will happen with the export propensity of the Norwegian defence industry, if the policy changes and the defence market is more liberalized.

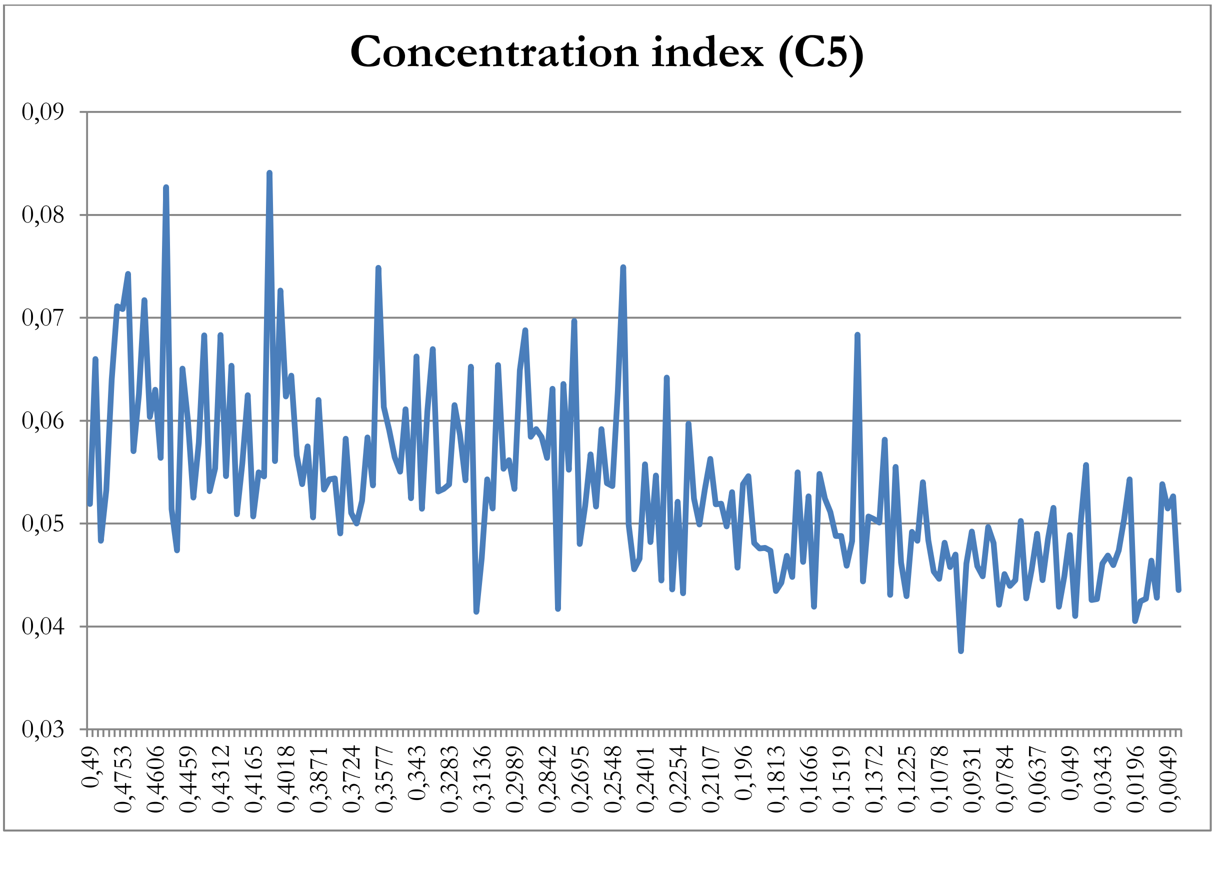
Figure 2: Effects of an increase in the cooperation propensity (X-axis) on the five industry-level outcome variables (Y-axis).




Product quality
7
6,5
6
5,5
5
4,5
4
0,49
0,4753
0,4606
0,4459
0,4312
0,4165
0,4018
0,3871
0,3724
0,3577
0,343
0,3283
0,3136
0,2989
0,2842
0,2695
0,2548
0,2401
0,2254
0,2107
0,196
0,1813
0,1666
0,1519
0,1372
0,1225
0,1078
0,0931
0,0784
0,0637
0,049
0,0343
0,0196
0,0049


New privately-funded R&D projects (%)
60
50
40
30
20
10
0
0,49
0,4753
0,4606
0,4459
0,4312
0,4165
0,4018
0,3871
0,3724
0,3577
0,343
0,3283
0,3136
0,2989
0,2842
0,2695
0,2548
0,2401
0,2254
0,2107
0,196
0,1813
0,1666
0,1519
0,1372
0,1225
0,1078
0,0931
0,0784
0,0637
0,049
0,0343
0,0196
0,0049


New publicly-funded R&D projects (%)
20
18
16
14
12
10
8
6
4
2
0
0,49
0,4753
0,4606
0,4459
0,4312
0,4165
0,4018
0,3871
0,3724
0,3577
0,343
0,3283
0,3136
0,2989
0,2842
0,2695
0,2548
0,2401
0,2254
0,2107
0,196
0,1813
0,1666
0,1519
0,1372
0,1225
0,1078
0,0931
0,0784
0,0637
0,049
0,0343
0,0196
0,0049


Concentration index (C5)
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,49
0,4753
0,4606
0,4459
0,4312
0,4165
0,4018
0,3871
0,3724
0,3577
0,343
0,3283
0,3136
0,2989
0,2842
0,2695
0,2548
0,2401
0,2254
0,2107
0,196
0,1813
0,1666
0,1519
0,1372
0,1225
0,1078
0,0931
0,0784
0,0637
0,049
0,0343
0,0196
0,0049

6.1.2 Success Threshold

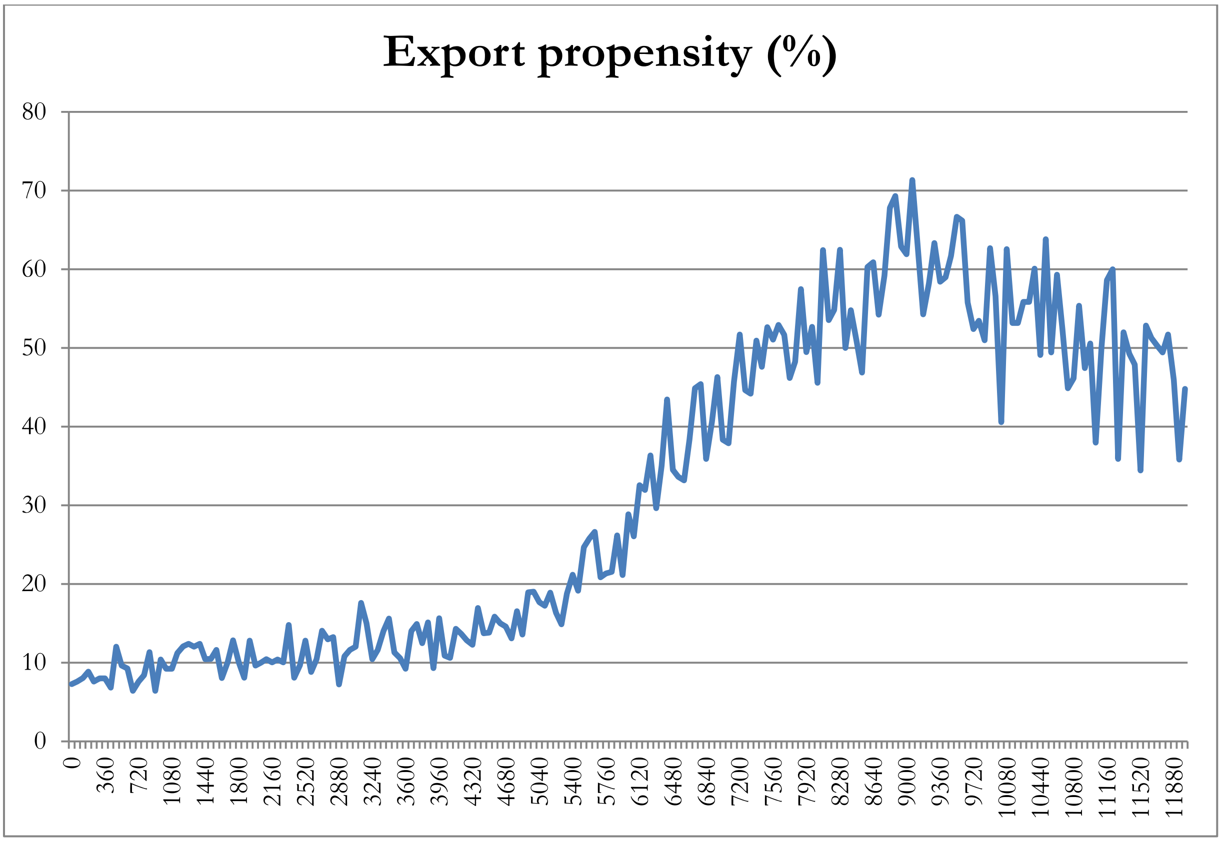
Result 2: The success threshold is characterized by an inverse U-shaped relationship with the export propensity.

The second result is shown in figure 3 (below) with five charts. The first chart of figure 3, mapping the relationship between cooperation propensity and success threshold, supports this result along with the other charts. The success threshold characterizes the degree of competition in the market. According to Melitz' theory (see section 3.5), due to a low degree of openness and competition in the domestic defence market, Norwegian defence firms do not prioritize high profit margins. This corresponds to a low success threshold. When the firms have relatively low profit targets they do not make the effort to increase their profit through private R&D, and the share of exporting firms, and firms who qualify for public funding, is low.

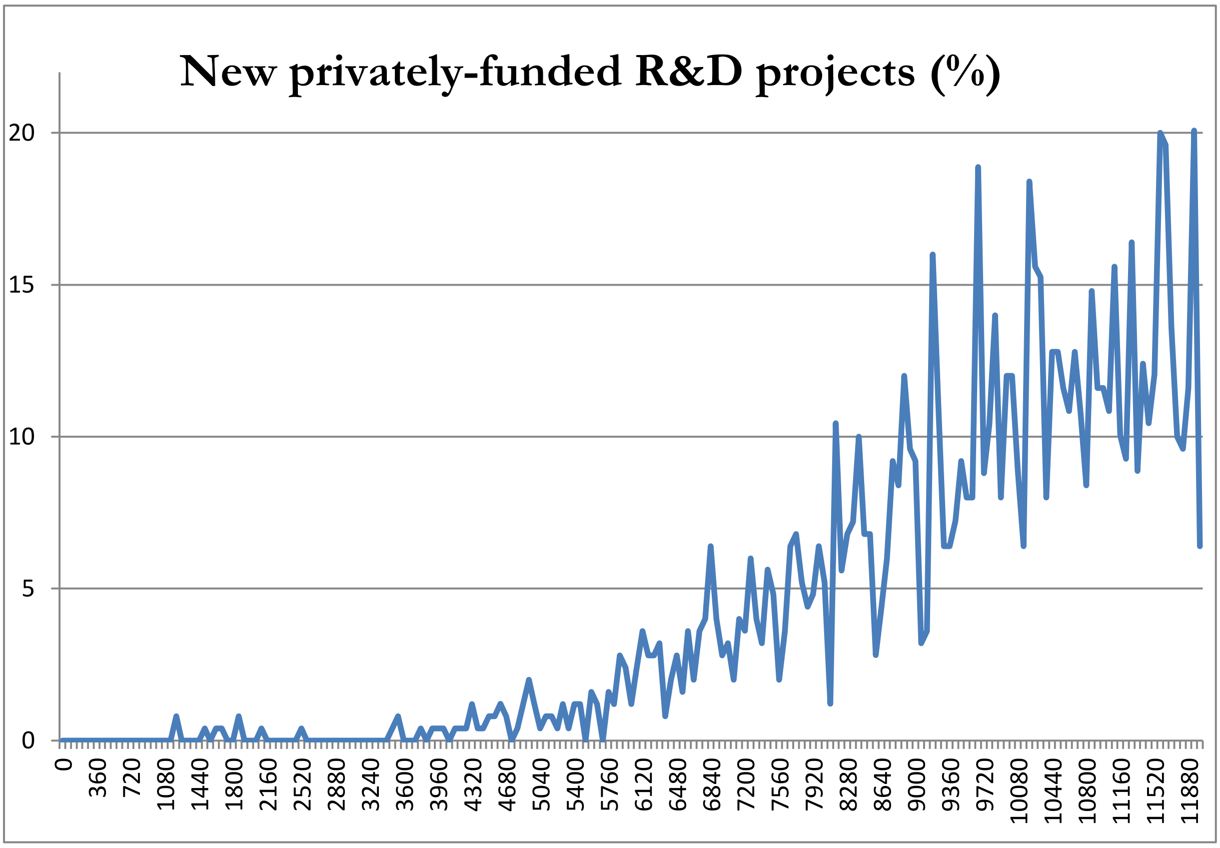
However, with increased openness in the market and more competition, the success threshold increases. An increase in this parameter leads firms to innovate more, the quality of the products increase along with profits, and the export propensity increases as well.

Even so, this cannot go on indefinitely. When the success threshold exceeds 9000, which correspond roughly to the average profit level in the market for all producing firms, the level of competition gets too high. They reach the limit of how much they can improve products through innovation, and they are no longer able to produce for the domestic market given the high profits required to succeed. This manifests itself amongst others in a decrease of export propensity. Fewer firms achieve the profit required to export. Result 2 as a long-run property of the model, is in total accord with Meltiz' theory on productivity and export performance. Since this result is analogous to possible effects of the introduction of the EU Directive, this result also has an important policy interpretation to be discussed later in section 6.3.

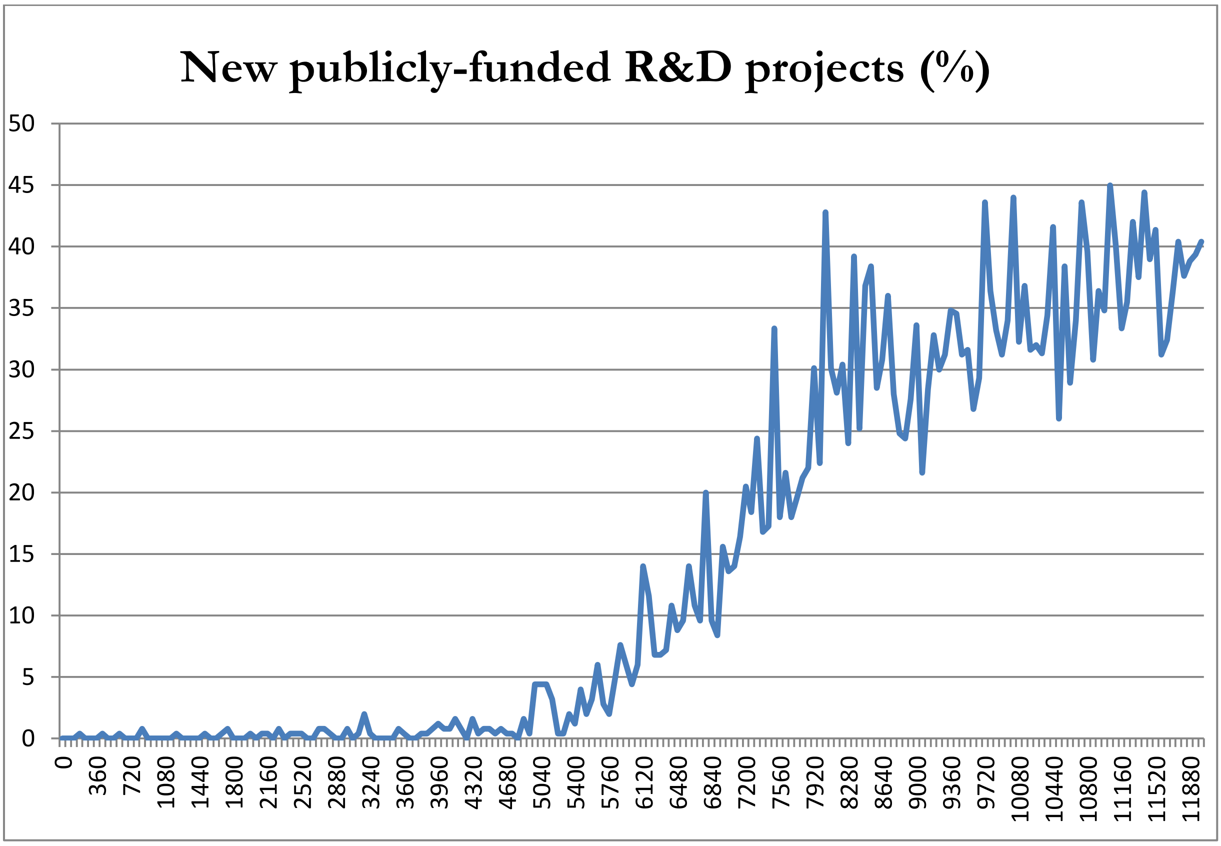
Figure 3: Effects of an increase in the success threshold (X-axis) on the five industry-level outcome variables (Y-axis).

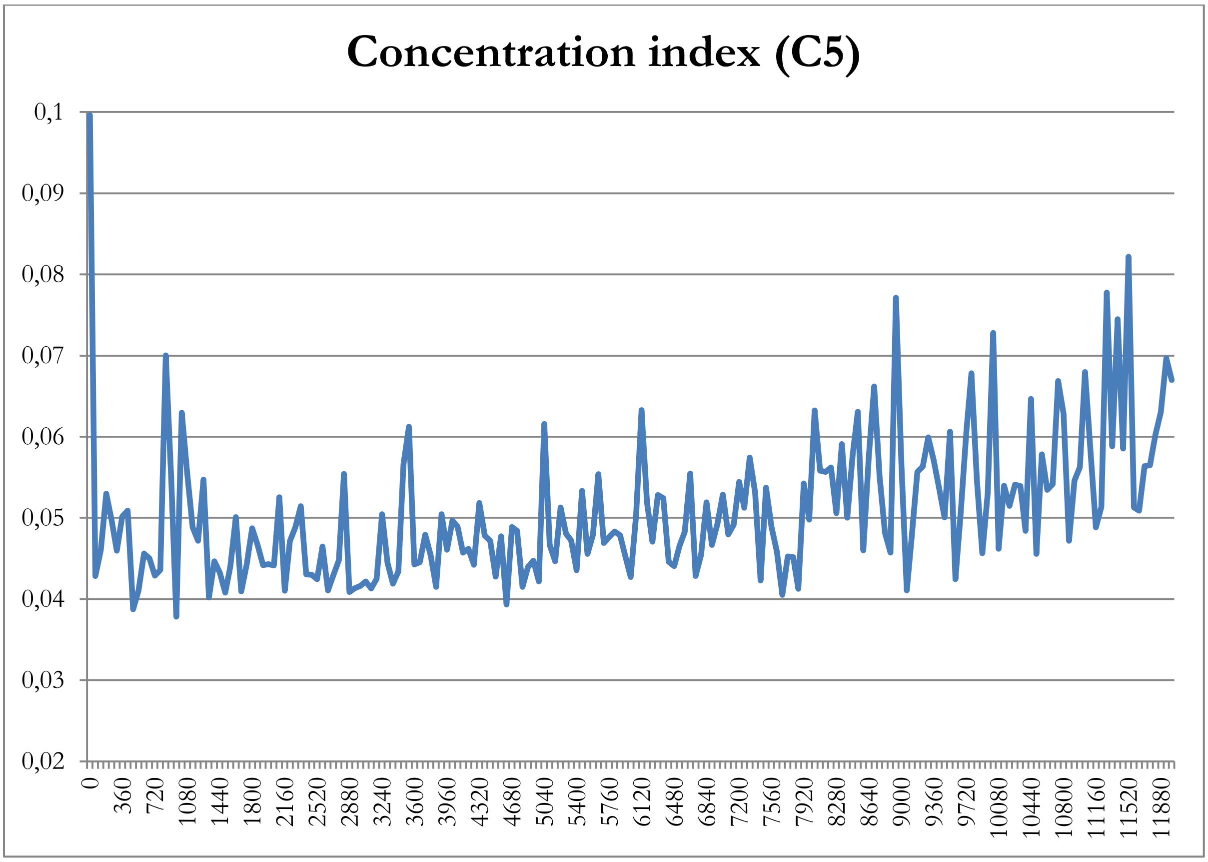


Product quality
8
7,5
7
6,5
6
5,5
5
4,5
4
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
5760
6120
6480
6840
7200
7560
7920
8280
8640
9000
9360
9720
10080
10440
10800
11160
11520
11880



New privately-funded R&D projects (%)
20
15
10
5
0
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
5760
6120
6480
6840
7200
7560
7920
8280
8640
9000
9360
9720
10080
10440
10800
11160
11520
11880


New publicly-funded R&D projects (%)
50
45
40
35
30
25
20
15
10
5
0
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
5760
6120
6480
6840
7200
7560
7920
8280
8640
9000
9360
9720
10080
10440
10800
11160
11520
11880


Concentration index (C5)
0,1
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0,02
0
360
720
1080
1440
1800
2160
2520
2880
3240
3600
3960
4320
4680
5040
5400
5760
6120
6480
6840
7200
7560
7920
8280
8640
9000
9360
9720
10080
10440
10800
11160
11520
11880

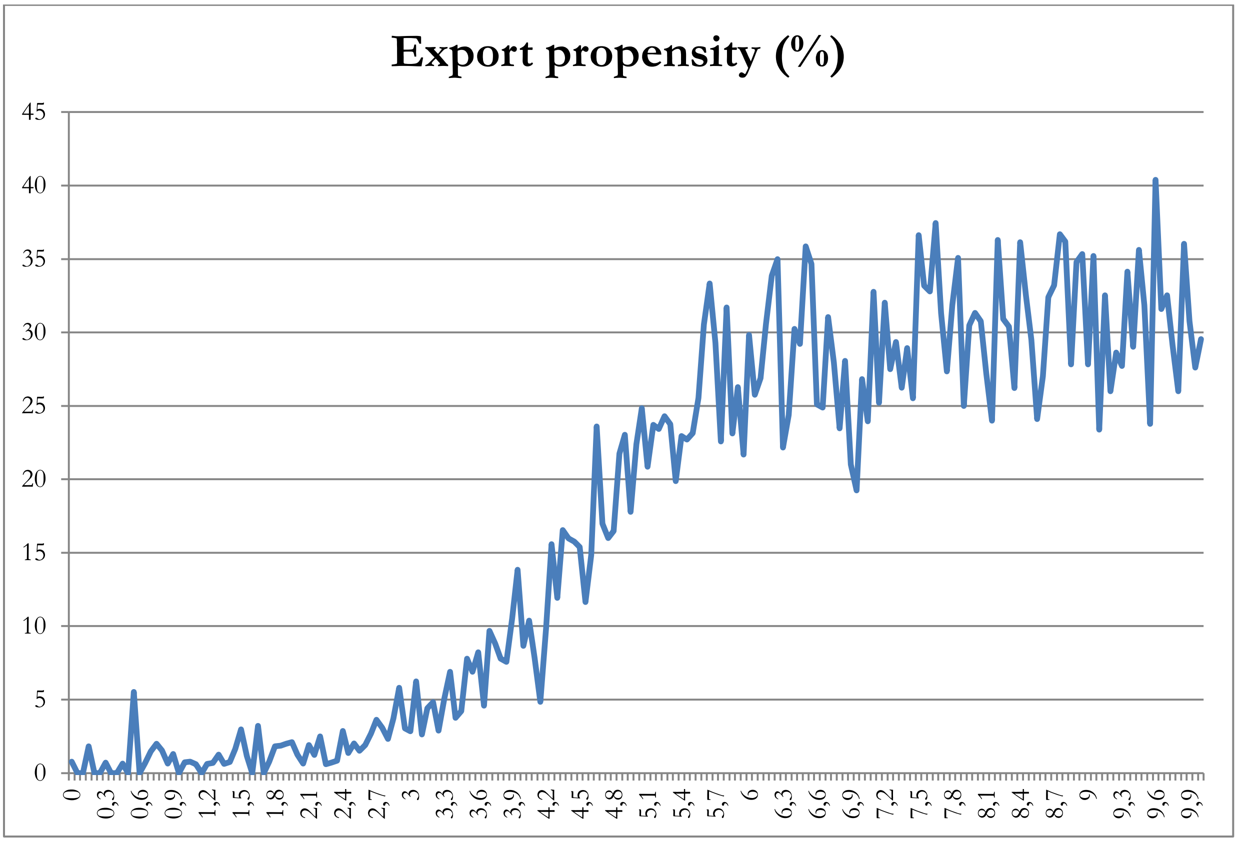
6.1.3 Product quality threshold

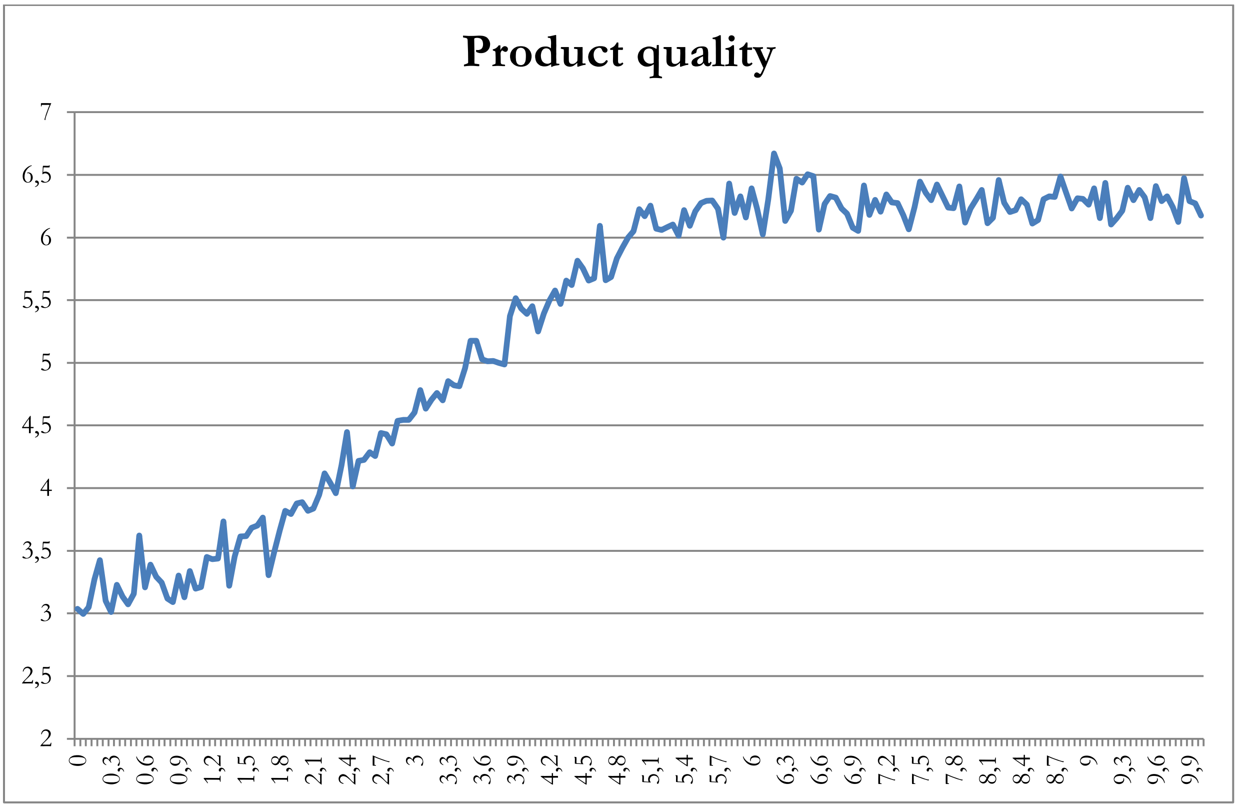
Result 3: The product quality threshold (public funding criterion I) and export propensity are positively correlated.

Result 3 is shown in figure 4 (below) with five corresponding charts. The charts portray the product quality as a function of each of the five aggregate variables. This result is an emergent property of the model supported by the charts in figure 4. The result seems to be similar to result 1, but it is caused by another mechanism, since the quality threshold focus on the role of the public agent rather than the effects of knowledge spillovers. When the criterion for public funding based on product quality is low, many firms have easy access. The first and direct effect is that many firms undertake publically funded innovation. One should think these public R&D projects induced a higher product quality, however they do not. An indirect effect is that firms achieve their profit target through the public funding, so they do not innovate on their own or try to improve their situation. The generous allocation of public funds allows firms to be satisfied and operate with poor product quality which results in a low export propensity. In this market environment, the concentration is higher, since firms with small profits do not try to improve them, and big firms are allowed to dominate the market.

If the public agent becomes more restrictive and sets a higher product quality requirement, the direct effect is that fewer firms do public R&D. This should result in a lower average product quality, but the indirect effect is stronger. Without public funds, firms actively seek to improve their product quality through private R&D in order to once again qualify for public funding. The resulting higher quality leads to more profit and a higher export propensity. With more firms trying to improve, the concentration in the market also decreases. Firms in the defence market model seems to manage better on their own, with more success doing private R&D than public R&D. Here it is convenient to employ the view of sectoral innovation systems (see theory section 3.3). That firms manage better by themselves, could be seen as a failure in the institutional dimension. From an SIS perspective a failure in the workings of the three dimensions has been identified. This has important policy interpretations since more restrictive public procurement strategies towards the Norwegian DIB is a possible outcome of a more open European defence market. More competition would force Norwegian defence firms to invest more actively in technology and quality upgrades in order to win public tenders.

Figure 4: Effects of an increase in the product quality threshold (public funding criterion I, X-axis) on the five industry-level outcome variables (Y-axis).




Product quality
7
6,5
6
5,5
5
4,5
4
3,5
3
2,5
2
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
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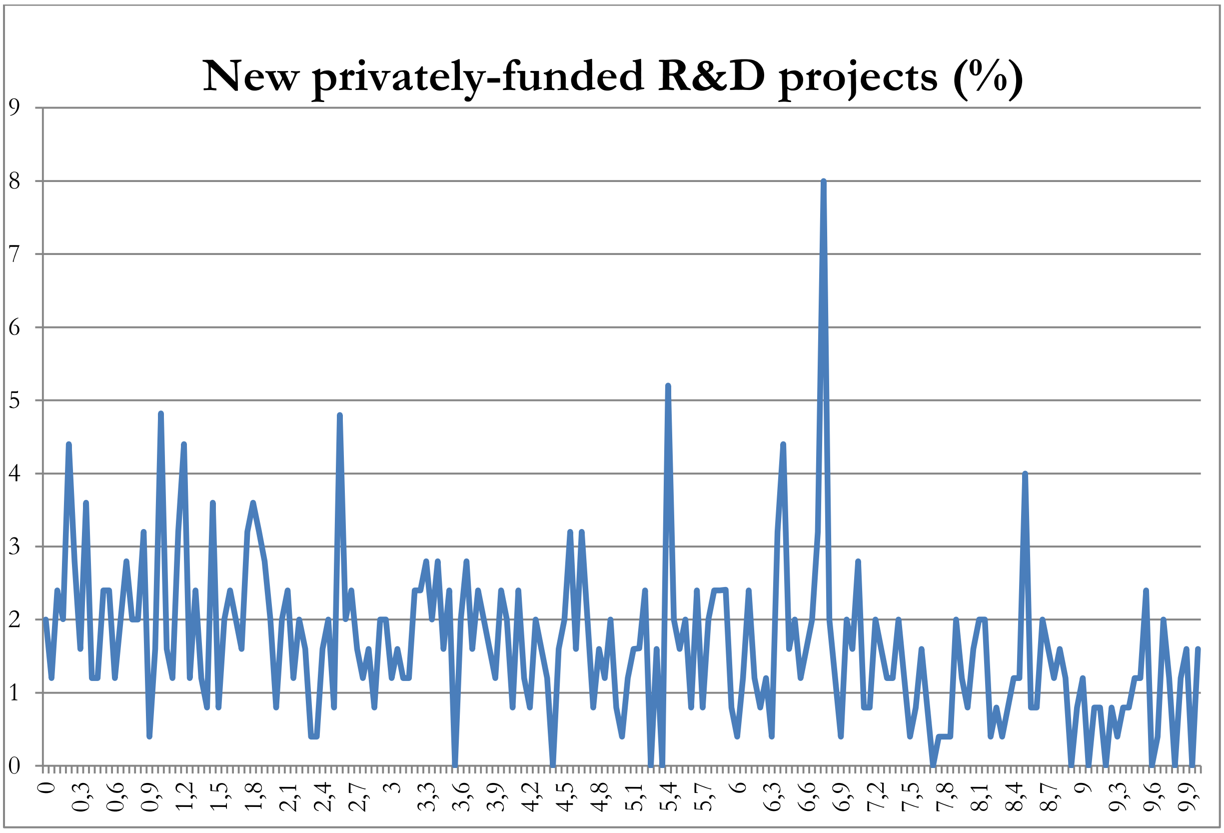
9
9,3
9,6
9,9


New privately-funded R&D projects (%)
9
8
7
6
5
4
3
2
1
0
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
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8,1
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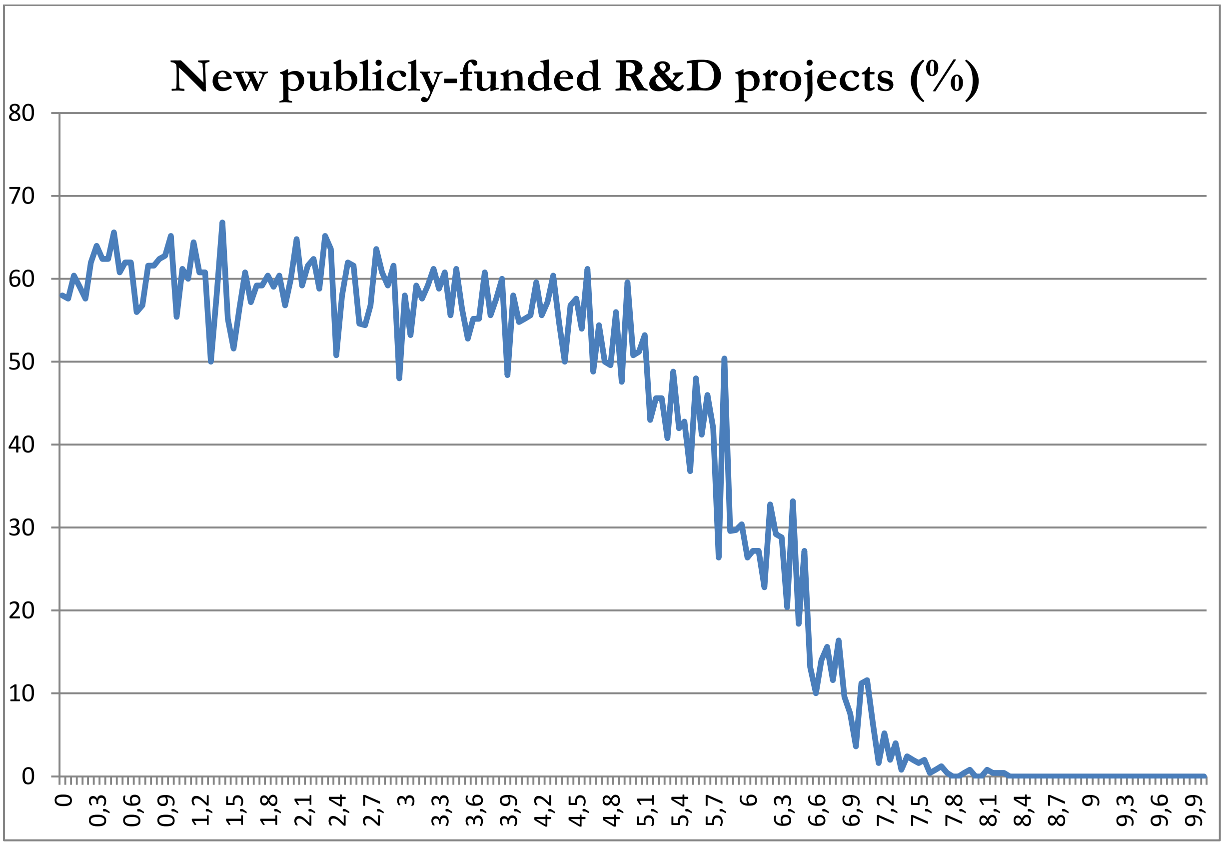
9,3
9,6
9,9


New publicly-funded R&D projects (%)
80
70
60
50
40
30
20
10
0
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
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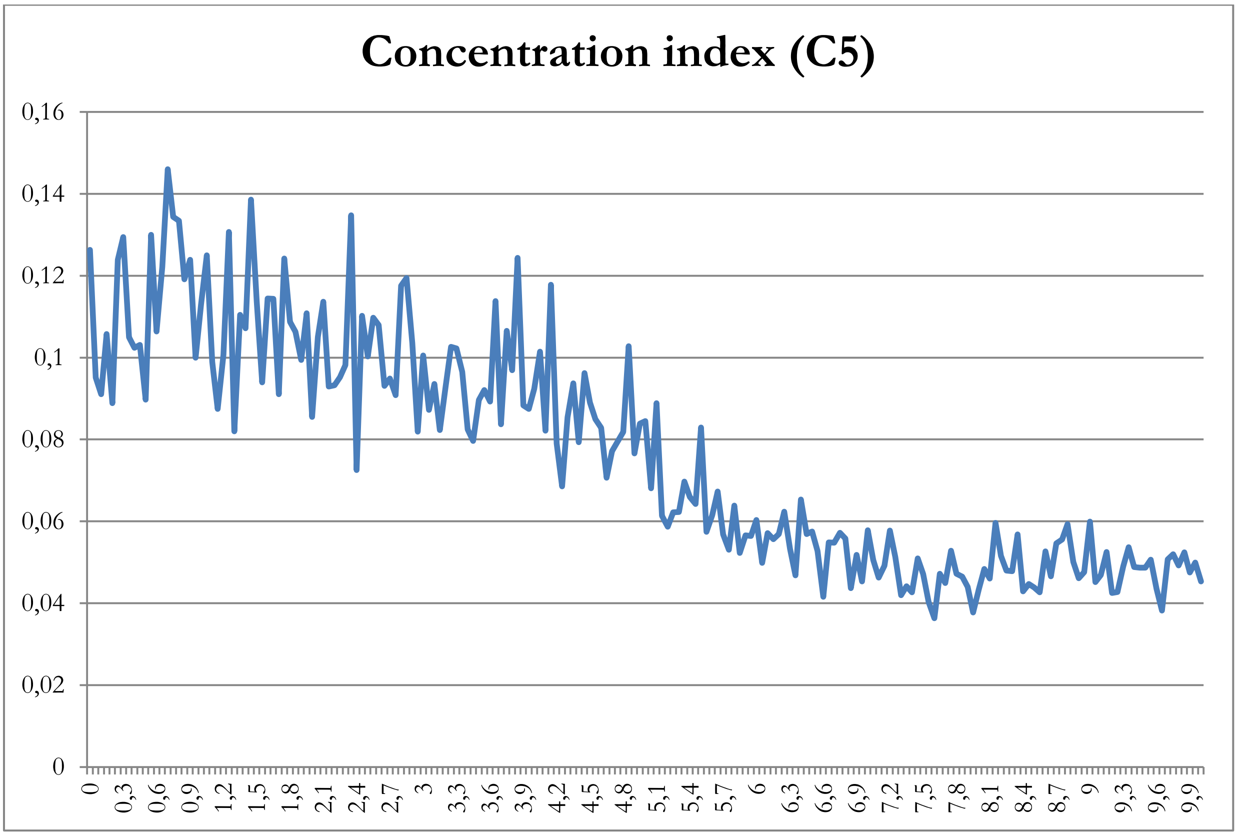
7,5
7,8
8,1
8,4
8,7
9
9,3
9,6
9,9


Concentration index (C5)
0,16
0,14
0,12
0,1
0,08
0,06
0,04
0,02
0
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
6,6
6,9
7,2
7,5
7,8
8,1
8,4
8,7
9
9,3
9,6
9,9

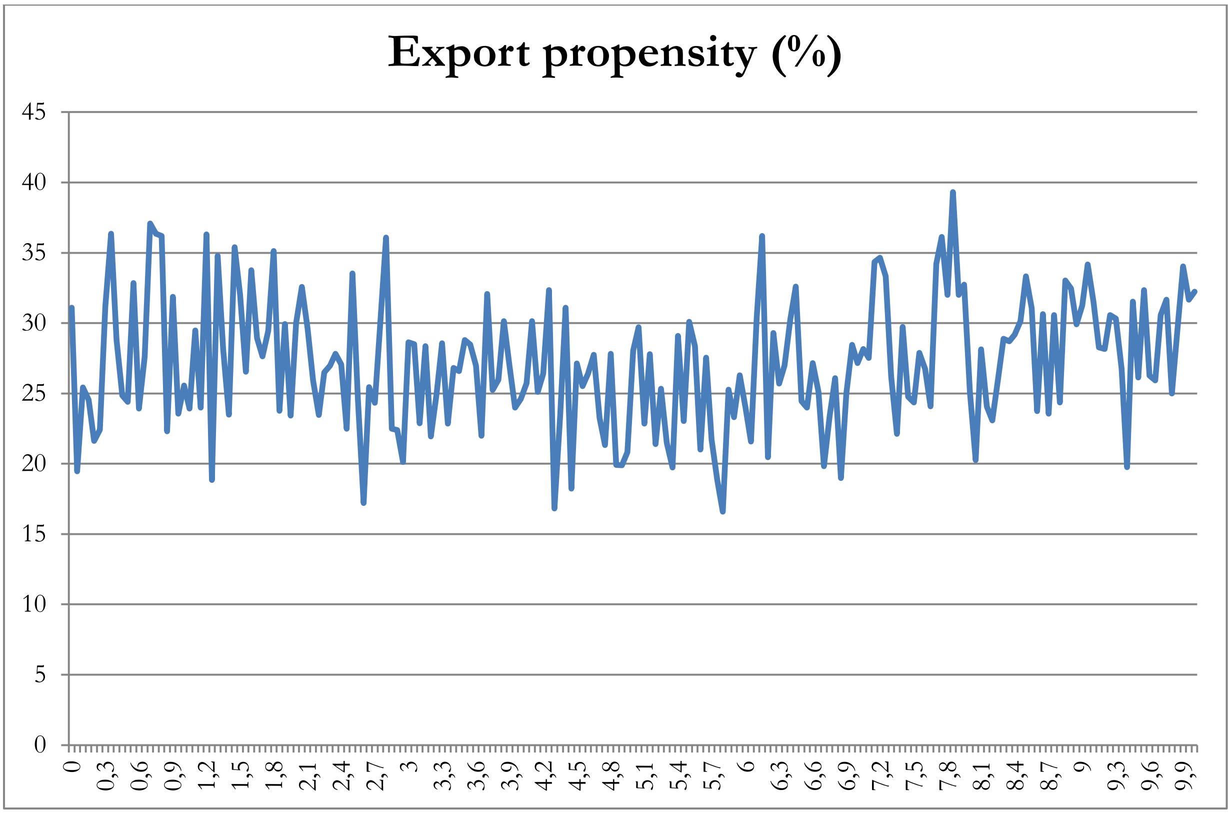
6.1.4 Competence breadth threshold

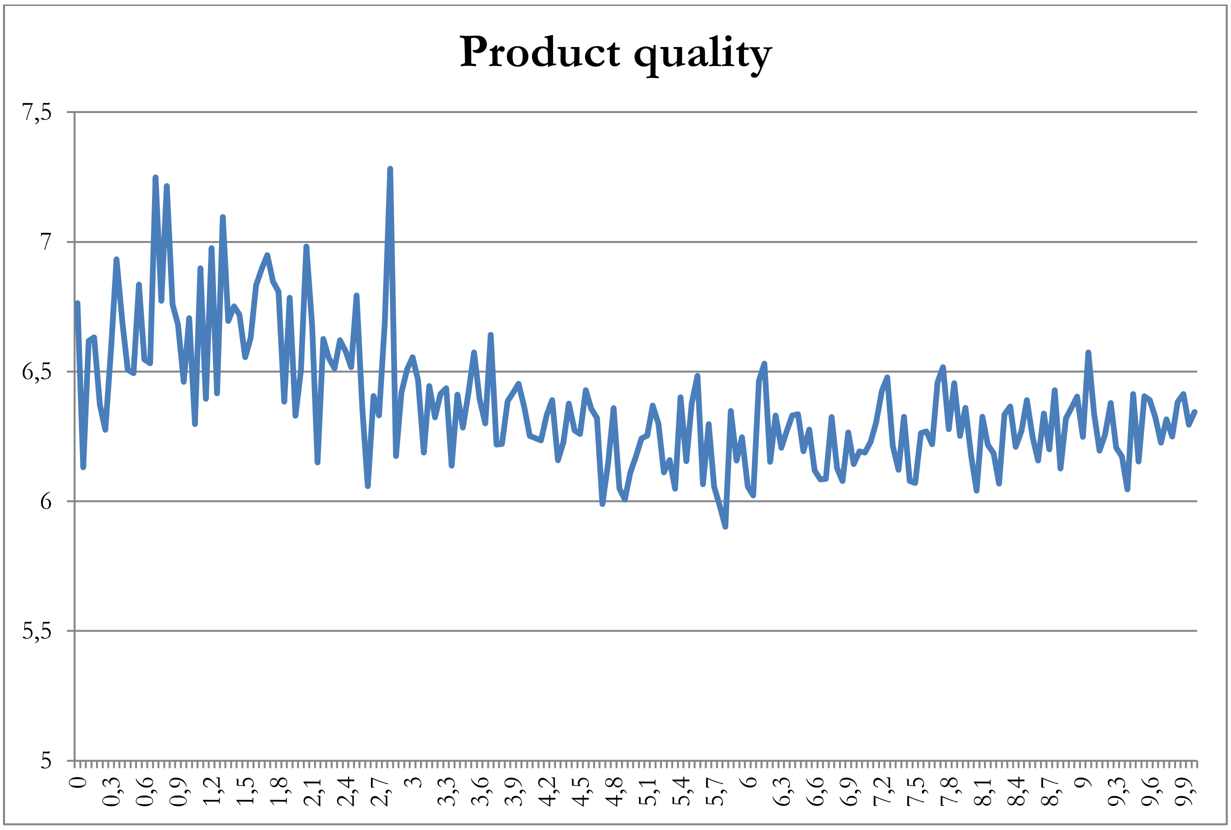
Result 4: A flat linear relationship between the competence breadth threshold (public funding criterion II) and the export propensity.

Result 4 is portrayed in figure 5 (below) with five corresponding charts. These charts show the relationship between the competence breadth threshold and the aggregate variables. The first chart of figure 5 shows this relationship for the competence breadth and the export propensity. If public authorities emphasize competence breadth, at the expense of product quality, as a funding criterion, this does not lead to an increase in the share of exporting firms. There is a straight forward explanation for this. With an increase in the competence threshold only progressively larger firms will have access to public funds. Profits are based on the quality of the products. With a higher competence threshold public authorities signal larger firms will get access to public funding, but they do not stimulate firms to pursue higher product quality. Since there is no indirect effect on the policy towards product quality it remains largely unchanged. For this reason firms are guided by the same 'satisficing behavior' in relation to product quality and profits all the time. This leads to a stable level of export propensity in the Norwegian defence firms. Looking at it again from an SIS perspective (see section 3.3) this result is interesting. If the motivation is to help the Norwegian defence industry increase its economic performance, a failure in the funding allocation mechanism has been identified. Public defence authorities cannot solely promote 'national champions' and ensure positive economic development for all defence firms at the same time.

There are policy interpretations in this result as well. It now seems clear the two different public procurement strategies have two different effects. The quality requirement in result 4 leads to a higher degree of exporting firms, whereas the competence breadth requirement does not seem to affect the export propensity.

Figure 5: Effect of an increase in the competence breadth threshold (public funding criterion II, X-axis) on the five industry-level outcome variables (Y-axis).




Product quality
7,5
7
6,5
6
5,5
5
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
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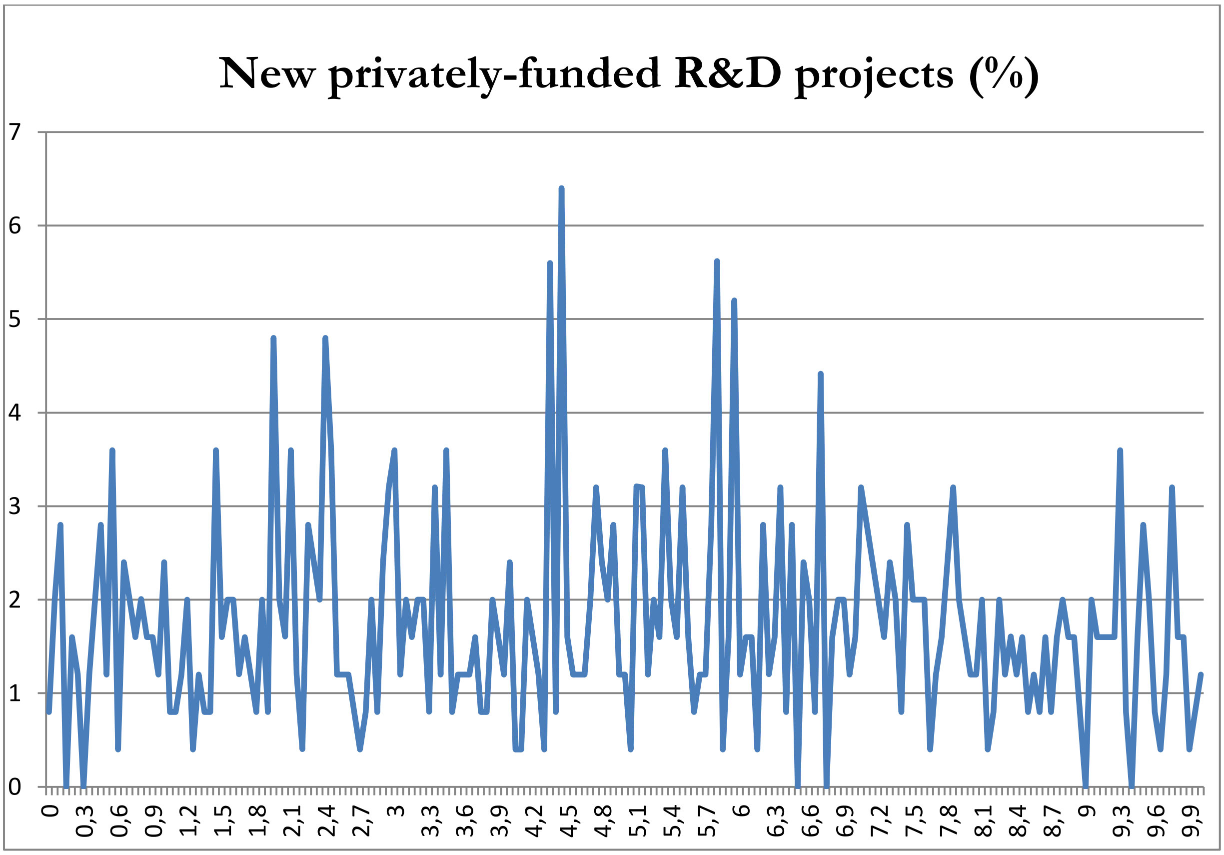
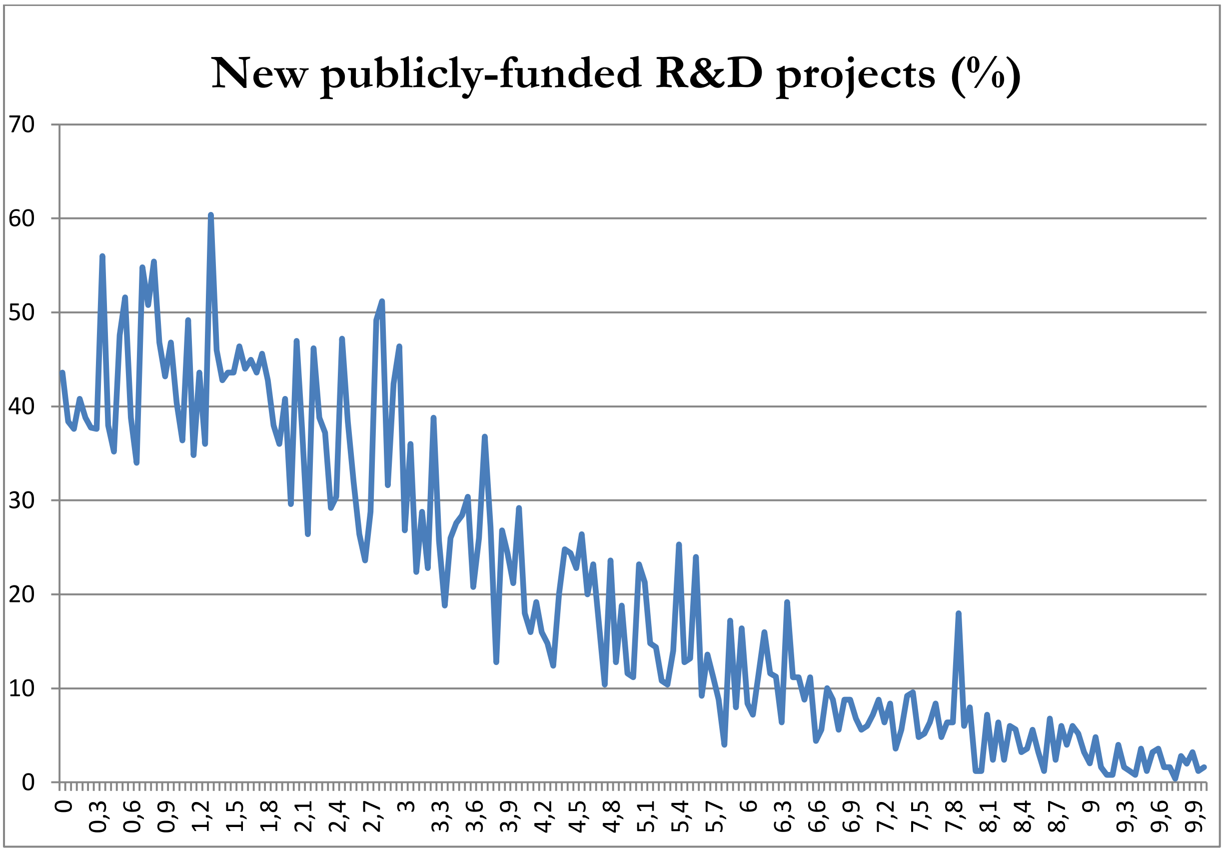
9,3
9,6
9,9


New privately-funded R&D projects (%)
7
6
5
4
3
2
1
0
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
6,6
6,9
7,2
7,5
7,8
8,1
8,4
8,7
9
9,3
9,6
9,9


New publicly-funded R&D projects (%)
70
60
50
40
30
20
10
0
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
6,6
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7,2
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7,8
8,1
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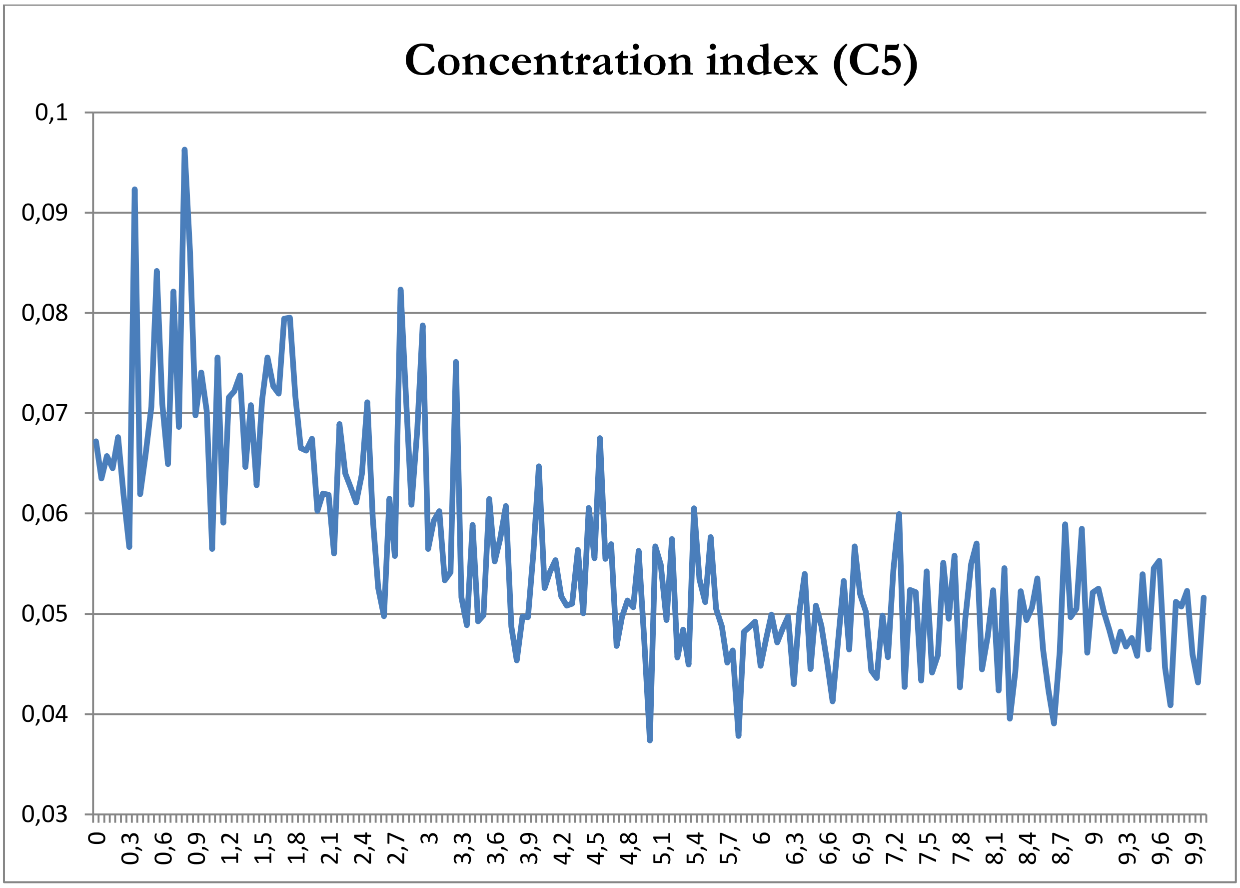
9
9,3
9,6
9,9


Concentration index (C5)
0,1
0,09
0,08
0,07
0,06
0,05
0,04
0,03
0
0,3
0,6
0,9
1,2
1,5
1,8
2,1
2,4
2,7
3
3,3
3,6
3,9
4,2
4,5
4,8
5,1
5,4
5,7
6
6,3
6,6
6,9
7,2
7,5
7,8
8,1
8,4
8,7
9
9,3
9,6
9,9

6.1.5 Statistical analysis exercise

Table 1 (below) presents the result of four regressions that point out the statistical relationship between firms' performance (profit and export participation), on the one hand, and technological breadth and depth, on the other. Profit and export participation are directly linked, so they are both an expression for export propensity. These results substantiate and provide further support for the analysis of the four long-run properties just discussed. The regression is based on firm panel data created from two of the scenarios presented in the next section: The current scenario and the full market liberalization scenario. This means the results are based on two of the calibrated scenarios presented in the next section. In order to study the endogenous interactions between the two explanatory variables (profit and export participation) a sample simulation of scenario 1 and 6 was run for 200 periods with 150 firms. From these simulations, two firm panel datasets was created. These are spread-sheets with all relevant data from each of the firms in every time period. They were analyzed in a statistical manner (linear and probit regression) with panel fixed effects estimations (FE).

This exercise is done to highlight a key property of the model: In both scenarios, firms' performance is positively and significantly related to their product quality, and negatively linked to the length of their innovation hypothesis. Looking at result (1), (2), (3) and (4) in table 1, both profits and export participation (a yes/no dummy) are strongly positively linked to product quality. In the same results both profits and export participation is strongly negatively linked to technological breadth. The results show an existence of a trade-off between technological breadth and depth in the model. Competence breadth embedded in a firm's product does not help profit or export participation. In stark contrast, the technological depth (quality) of a firm's product has a strong positive impact on profits and export participation. This result is consistent with the main intuition behind the long-run properties and the analysis of the different scenarios presented in the next section.

Table 1: Regression results: Firms' profit and export activities as a function of their product quality (technological depth) and innovation hypothesis length (competence breadth) – Panel fixed effects estimation (FE) on the simulated firm-level dataset.

	(1)	**(2)**	**(3)**	**(4)**
Scenario	*Current*	*Market liberalization*	*Current*	*Market liberalization*
Estimation method	Linear FE	Linear FE	Probit FE	Probit FE
Dependent variable	Profits	Profits	Export dummy	Export dummy
Product quality (*technological depth*)	3484.86 (21.32)***	2820.03 (38.5)***	0.9452 (20.41)***	0.8780 (53.50)***
IH length (*technological breadth*)	-1960.12 (-20.19)***	-905.45 (-20.84)***	-0.1382 (-6.60)***	-0.0346 (-4.67)***
Year	10.95 (7.88)***	-4.46 (-2.60)***	0.0055 (16.11)***	0.0023 (7.74)***
Observations	30150	30150	26130	29547

The regressions include a constant. Significance levels: ***: 1%.

6.2 Analysis of six different policy scenarios

This section makes use of the four results above to analyze and compare six different policy scenarios. The analysis here is different from the long-run properties study. Here, the model is calibrated to represent 6 different scenarios. Then the simulation is run, and data on aggregate outcome variables from how these scenarios evolve over time is collected. The results are displayed in figure 6 (below) with five charts. Each chart shows how the scenarios evolve with respect to one of the aggregate variables. This means the first chart shows how the export propensity evolves over time for all the six scenarios. The remaining charts show the evolution for the other aggregate variables.

The model is set up to simulate six different policy scenarios. The first is a replication of the current situation in the defence industry today. Scenarios 2 – 5 simulate different policy approaches to the market liberalization imposed by the EU Directive. Scenario 6 is a combination of all the strategies in scenarios 2 – 5 combined in one simulation called 'full market liberalization'. Each scenario is run 20 times for 300 periods (at which point the model is very stable). Data on the evolution of the five aggregate variables during the 300 periods are collected and presented in charts. The individual graphs in the charts are an average of 20 replications of each scenario to ensure the reported values are robust to random shocks in individual runs of the simulations.

The entire model is made to simulate the Norwegian military-industrial-political complex. However, in the scenario called '*current*' it is calibrated to be a replication of the current public procurement situation today. It is calibrated to fit the number of firms (150), export propensity (38%), concentration index (0.75) and an environment with a high degree of national protection and a more closed market resembling a Schumpeter Mark II regime. This scenario is then compared to the other five scenarios. They represent possible future trajectories for the defence industry based differing public procurement strategies in regard to the implementation of the EU Directive.

(1) ***Higher success threshold scenario:*** In this scenario policy makers do not make any change to their strategy. The defence market is characterized by a stronger degree of competition in the domestic market due to an opening up of this market. Accordingly they have raised their success threshold, and this is the difference from the current scenario.

(2) ***Higher cooperation scenario:*** As described in section 2.4 the possibility of doing multi-national cooperation projects including R&D without public tenders exists in the EU Directive. If Norwegian authorities choose to facilitate and promote these projects it would increase the cooperation propensity of Norwegian defence firms. Based on what this scenario represents, firms cooperate more in this scenario than in the *current*.

(3) ***Higher product quality threshold scenario:*** In this scenario public authorities engage in tenders with an emphasis on product quality where the firm with the best product quality wins. Due to foreign competition it is natural to assume the quality requirement is higher to win the tender than if only Norwegian defence firms had participated in the tender. This scenario explores the consequence of the increased product quality requirement.

(4) ***Increased competence breadth threshold scenario:*** By contrast to the last, this scenario explores what happens if public authorities emphasize the second allocation criterion, competence breadth, in the public tenders.

(5) ***Full market liberalization scenario:*** This scenario explores the effect if all the policy strategies outlined above are combined and implemented together, and the market is fully liberalized. This corresponds to a rapid implementation of the EU Directive and a radical way of introducing the liberalized market.

(1) The second scenario, *higher success threshold,* is characterized by a more rapid increase in export propensity over time, and it stabilizes at a 46% value. Firms are on average more responsive to market opportunities and more actively investing in private R&D than what they do in the *current* scenario. In this scenario, the share of firms doing private R&D is highest, due to the increased competition. The reason for this is found in result 2 (see section 6.1.2). This emergent phenomenon shows that a higher degree of competition is good for the export propensity. This is in line with what is expected from the theory of evolutionary economics. However, the average product quality level is not much increased, but Norwegian firms are still more likely to win public tenders due to the increased focus on private R&D.

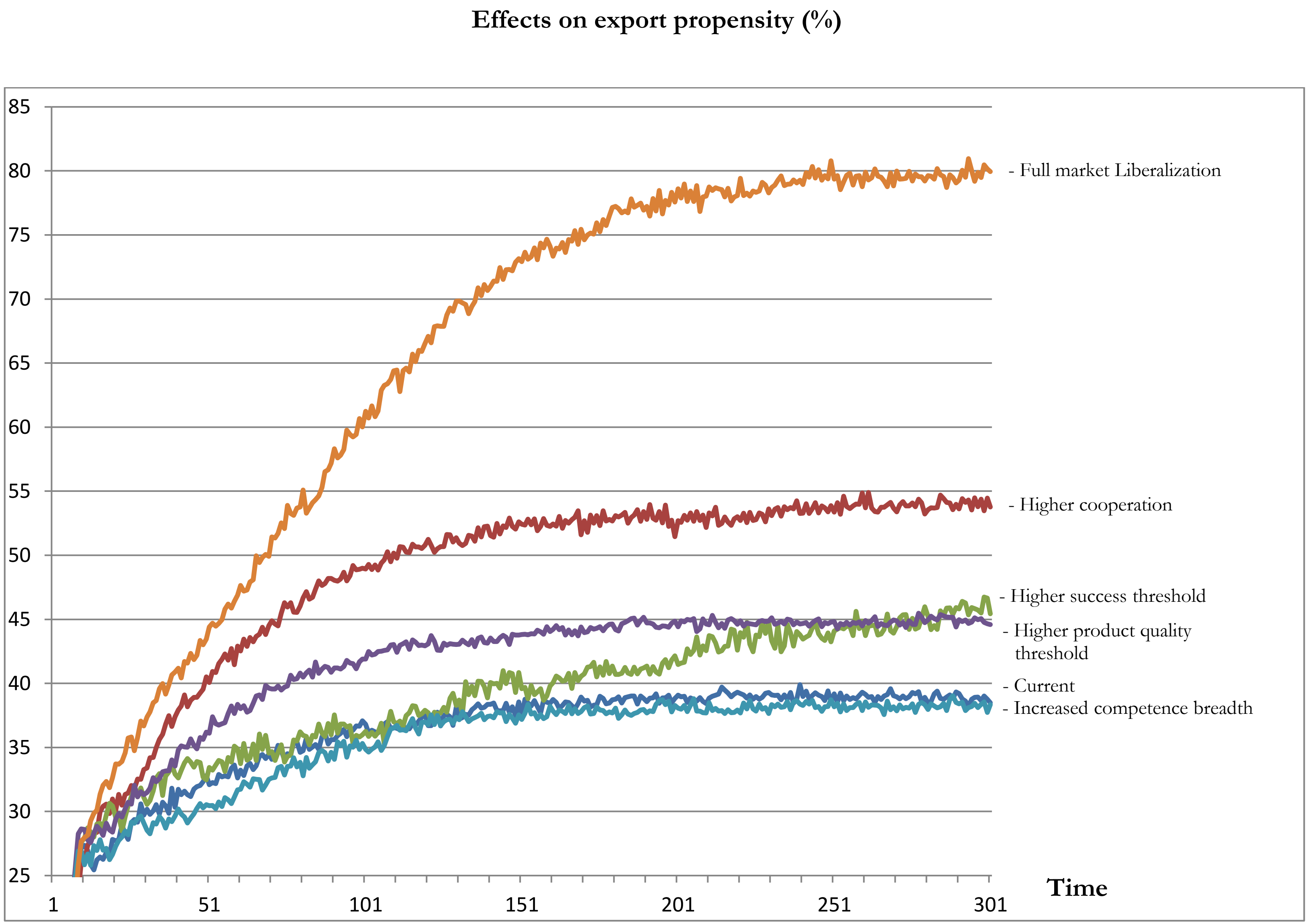
(2) The third scenario, *higher cooperation*, is the one where firms engage in more multi-national cooperation projects. Because of the positive effects of imitation and knowledge spillovers, this scenario outperforms the *current* scenario (see result 1, section 6.2.1). The strong effect of the imitation catch-up mechanism allows firms to be much more likely to win public tenders (see the fourth chart in figure 6).

(3) The fourth scenario, *higher product quality threshold*, is the one where public authorities increase the requirement to win public tenders based on product quality. Despite firms having a harder time to win the public tenders, the underlying emergent effects allow the export propensity to stabilize at a 45% value. The reason for this is outlined in result 3 (see section 6.1.3).

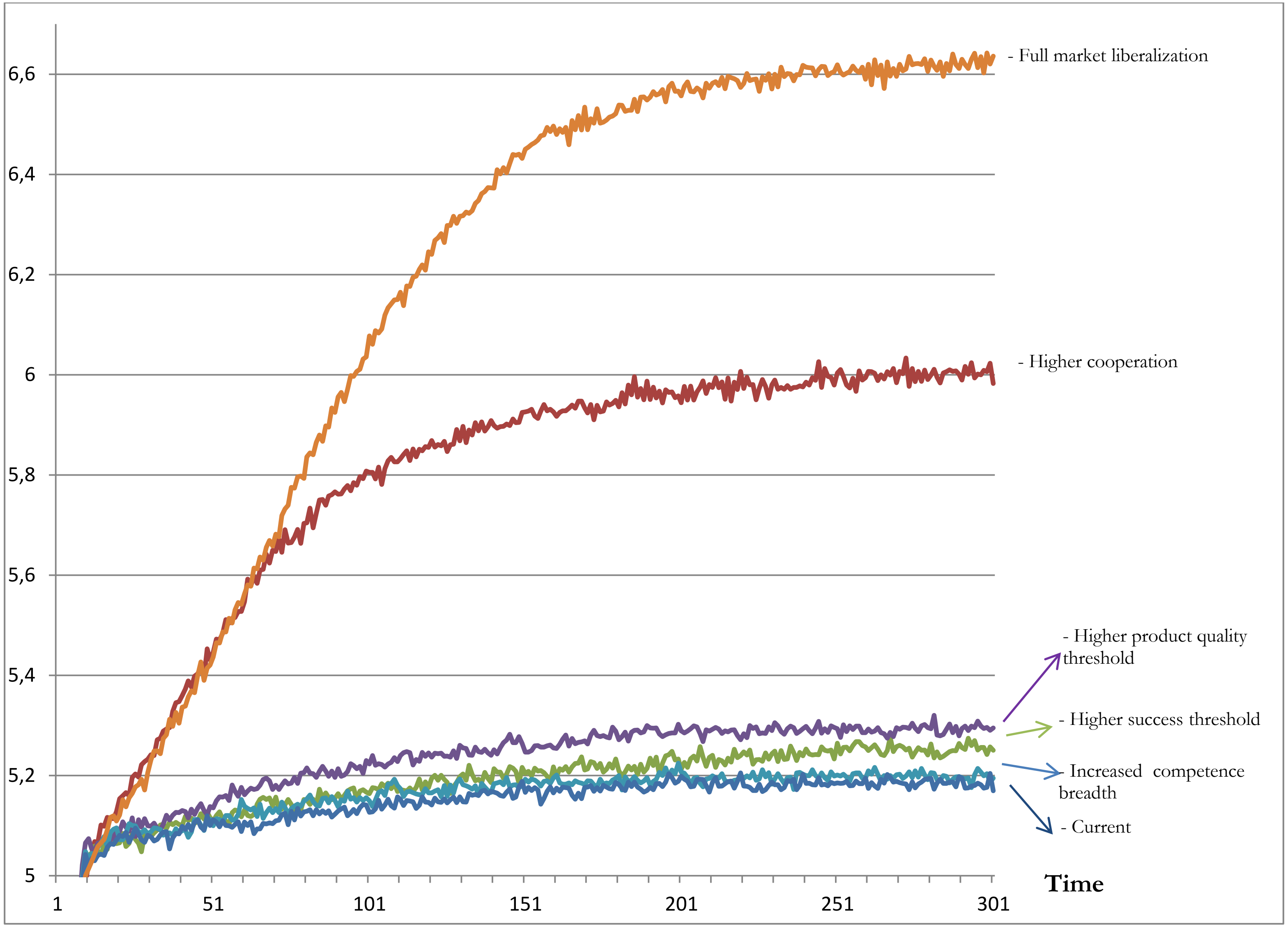
(4) The fifth scenario, *increased competence breadth threshold*, stands in contrast to the previous scenario and the resulting export propensity is quite similar to the *current* scenario. The reason for this is (as discussed in result 4, section 6.1.4) that this criteria is not in line with the market requirement to compete with international firms (technological depth). In the scenario large oligopolistic firms are favored and the resulting concentration index is slightly higher than in the *current* scenario.

(5) The last scenario, *full market liberalization*, clearly outperforms all other policy scenarios with respect to the export propensity. Here the transition to a more open and competitive market has been swift. There are different emerging phenomena relevant to each of the four previous scenarios which work alongside each other to produce this strong and combined effect. It is characterized by the highest export propensity and lowest industry concentration.

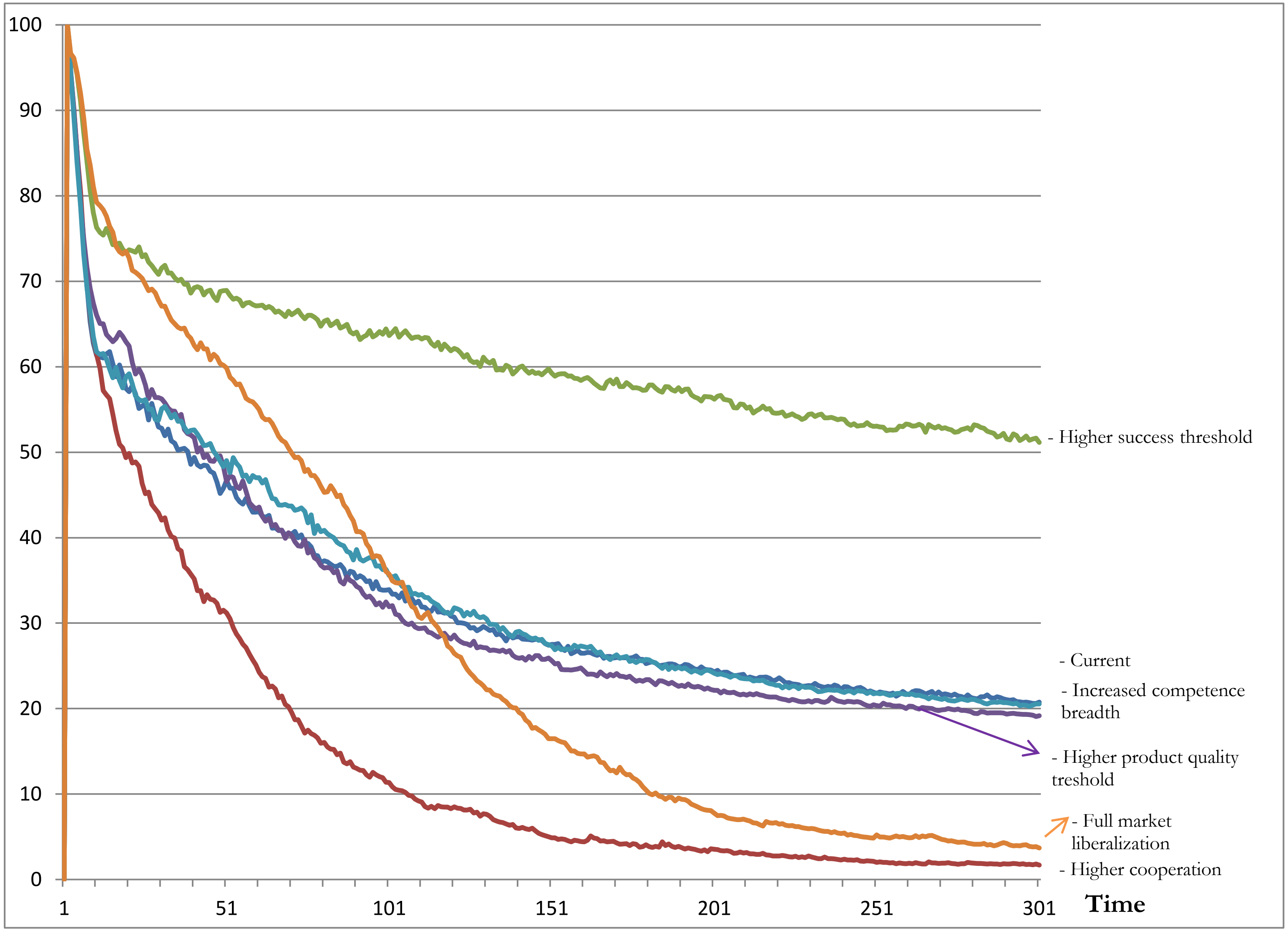
Figure 6: Simulating six different policy scenarios

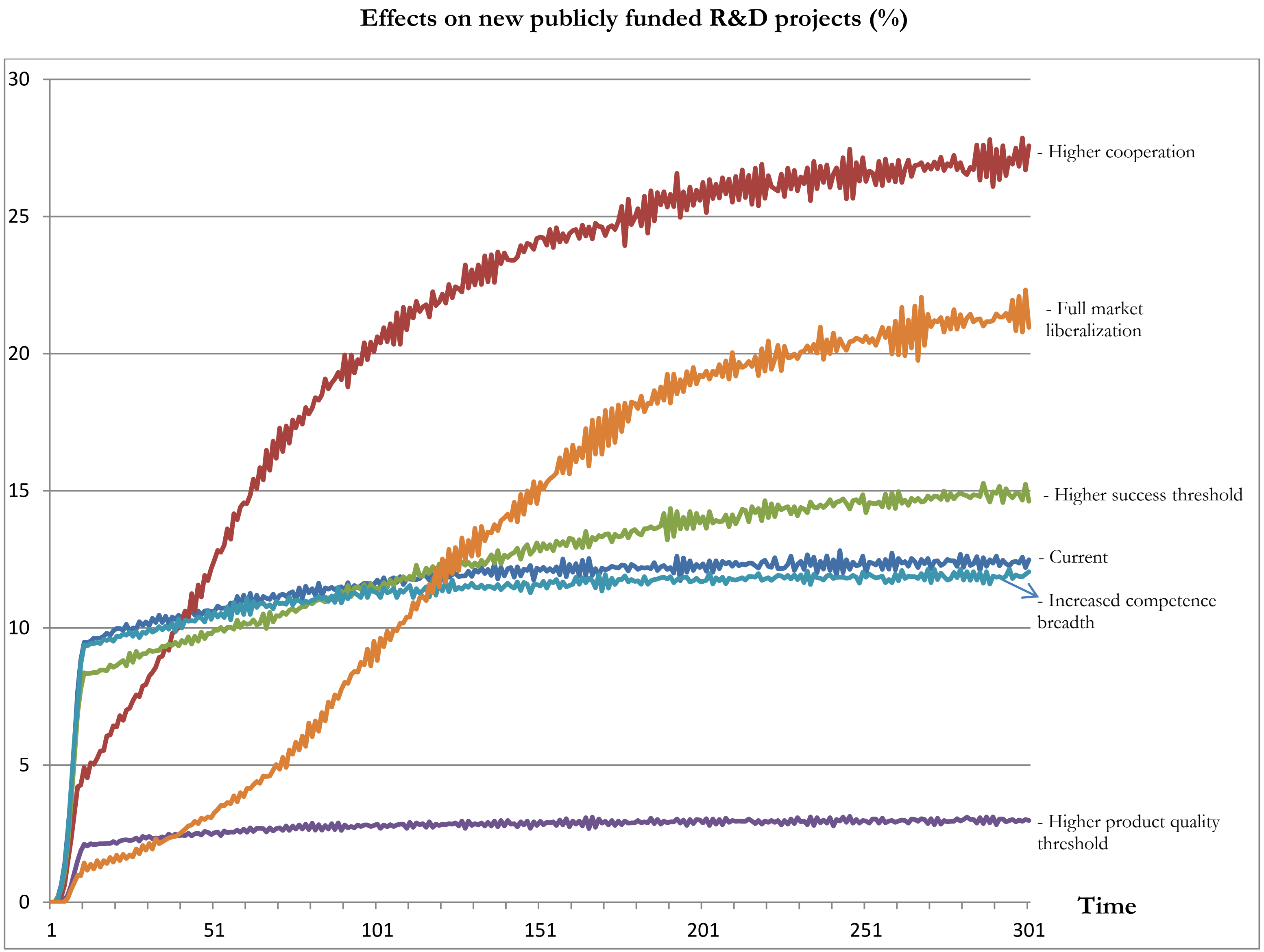


Effects on product quality

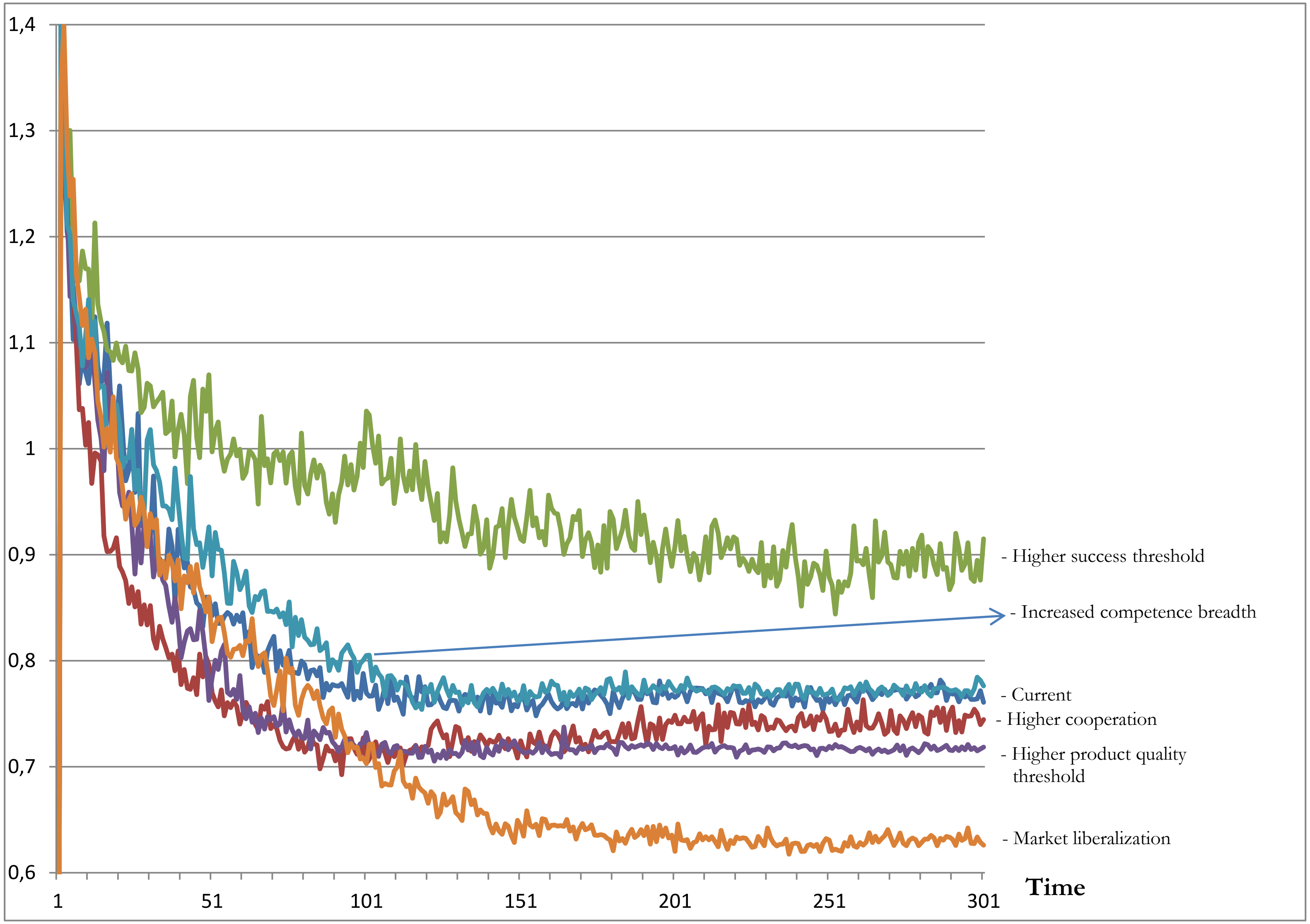


Effects on new privately funded R&D projects (%)




Effects on new publicly funded R&D projects (%)
30
25
20
15
10
5
0
1
51
101
151
201
251
301
Time
- Higher cooperation
- Full market liberalization
- Higher success threshold
- Current
- Increased competence breadth
- Higher product quality threshold

Effects on the concentration index (C5)



7 Summary and conclusions

The thesis has presented an agent-based simulation model of the Norwegian military-industrial-political complex. The model is set up so that it resembles some of the key stylized facts of the Norwegian defence industry. It studies the change in firms' innovative capabilities, by a shift towards market liberalization, and how innovative capabilities affect export performance. This analysis is timely due to the introduction of the new EU Directive (2009/81/EC) and the dawn of agent-based modeling in innovation studies. It is therefore important to investigate how micro-level agents (defence firms) in the Norwegian market will respond to these challenges and opportunities. At the same time, this novel type of model presents a valuable contribution to the innovation studies literature, since a similar study has never before been carried out.

7.1 Research question and strategy employed

The research questions investigated in this thesis are:

1. How does firms' innovative capability affect export performance in the Norwegian defence industrial base with the current offset market structure?

2. With the EU Directive 2009/81/EC there will be a change in public procurement policy and market conditions. Different policy scenarios are possible. How will the change in policy and market environment affect the relationship between firms' innovative capability and export performance?

Main theoretical arguments from the theoretical framework state that the military-industrial-political complex in Norway viewed as a sectoral innovation system, is composed of three dimensions: (1) The knowledge and technological domain, here characterized by firms' knowledge base in the model and a Schumpeter Mark II regime. (2) Actors and networks, here the actors are the firms and the public agent simulated in the model. The networks are all the links which arise in the model between firms selling, buying and engaging in partnerships along with the link to public authorities. (3) Institutions, which here are all the rules the firms follow to do product development and market interactions in addition to public procurement strategies employed in the model.

The arguments of evolutionary economics, stating that innovation is the driving engine for economic development, are complementary to the SIS literature. The theory on the relationship between productivity and export, by Melitz, is integrated with evolutionary economic theory. These three theoretical strands together, constitute a solid descriptive and analytically tractable theoretical framework used in the thesis.

To answer the research question in light of the theoretical framework the thesis considered agent-based modeling as the appropriate approach. The research strategy was to make up a clear picture of the Norwegian defence industry with all its idiosyncrasies, and embed this into a model capable of analyzing firms' innovative capability and export performance. The innovative capability is defined by their knowledge base, and how they are able to improve it through innovation. The analysis of the empirical findings is used to answer the research questions.

7.2 Summary of results

The analysis of the model provides a clear answer to research question 1. The current scenario with its public policies limits firms' innovative capabilities. Of all the possible scenarios analyzed by the model, the limited innovative capability in the current scenario results in the second lowest export propensity. A limited innovative capability is disadvantageous for firms' export performance. The current scenario with national protection imposes a low cooperation propensity and success threshold. This limits firms' innovative capability, and the low export performance in the Norwegian defence industry emerges as a result of this.

The analysis of the five possible policy scenarios point out three main findings relevant to the second research question. First, the increased competition in a more open market environment press firms to increase their success threshold, or profit level. This changes the conditions for undertaking innovation. Firms tend to invest more actively in technology and product quality upgrading, thus increasing overall industry performance and export propensity. More competition induces higher innovation activity, and consequently an increased export performance emerges.

Secondly, a change towards more intra-industry and cross country cooperation allows firms to take advantage of knowledge spillovers. The increased knowledge-level stimulates innovation, changes the innovation conditions, and has a positive effect on industry performance and export propensity. The study shows firms take advantage of these knowledge spillovers and the opportunities that arises with an accordingly positive increase in export performance. Finally, the scenarios and statistical analysis show that there is a trade-off between strategies pursuing technological depth (product quality) versus competence breadth in product development. If firms choose to broaden the competence base embedded in a product at the cost of specialization and quality, this has a negative impact on export performance. If they instead choose to specialize and focus on quality in innovation activity, this has a positive effect on export performance. This has a clear policy implication to be discussed in the next section.

7.3 Policy implications

There are specific policy implications which can be derived from the empirical findings and analysis. However, they should be viewed with caution since the model is not a perfect replica of the defence industry. Even so, a direction of change emerge which should be reliable. If public defence authorities do not change their policy, the implementation of the EU Directive will still have a positive impact on the export performance in the industry. Increased competition from abroad will increase export propensity, as long as the competition is not too high. Secondly, should public defence authorities decide to use the possibility to engage Norwegian defence firms in multi-national cooperation projects this will have a strong positive effect on export propensity. Shared knowledge pave the way for better innovative capabilities and increases export performance in the Norwegian DIB.

Finally policy makers are confronted with a choice in the funding allocation mechanism. If they want to promote 'national champions', large oligopolistic firms, this does not necessarily increase industry export performance. However, should they choose to support firms to specialize and focus on core competences, this will have a positive effect on the share of exporting firms.

7.4 Contributions to theory

Besides answering the research questions, there has been an ambition in this thesis to provide a contribution to the literature on innovation studies. There are previous agent-based models rooted in evolutionary economics and the innovation literature who study the ICT and pharmaceutical sector. In addition, most of them focus on reproducing stylized facts. There are very few attempts to derive policy implications from 'what-if' scenarios. However, none of them has studied the military-industrial-political complex. This is unchartered territory and this thesis provides the first roadmap. What this thesis has done is to review the innovation literature and provide a theoretical framework that along with the methodology is capable of providing important policy implications based on sound theoretical propositions to decision makers. That is a novel contribution to the academic field of innovation studies.

7.5 Limitations and further research

The master thesis is limited by the number of words, and there are limiting considerations in the methodology which justify further research. Effects on concentration or R&D propensity have not been properly analyzed due to the word limit.

As discussed earlier in chapter 4, the methodology applied is not necessarily suitable for quantitative predictions. The results are not a 100% certain prediction of future export propensity. This applies to the other aggregate variable outcomes like R&D activity, product quality and industry concentration as well. The results should be viewed qualitatively as a direction of change in the export propensity. Even though agent-based modeling is strong at providing qualitative results, the results from this model should be interpreted in the right context. However, there are many possible ways to improve the model.

The model in itself is not an accurate model of the Norwegian military-industrial-political complex. The political dimension of the defence industry is just partly integrated into the model. Fortunately by improving the strategies employed by the public agent in order to have a more realistic offset regime, the political dimension would be more accurate. Further areas for improvements consist of calibrating the knowledge base. Now the model consists of a random knowledge base in the firms. This is easy to remedy by introducing a calibrated knowledge base. The data on the knowledge base are available. Unfortunately, there is a lack of path dependency in the model. Firms can suddenly produce totally new products and there is always an end-user demand. This may to some extent disrupt the validity of the results. Even so, the results are a good estimation of firms' export performance given the framework conditions for the innovative capability in the different scenarios. The interaction between different innovative capabilities and export performance in isolation should not be disturbed by these limitations, and as such provide a good qualitative indication for the different scenarios.

In future research one may scale up the model and implement a real foreign market. Then the model could provide policy implications for EU and the future development of the international defence industry.

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