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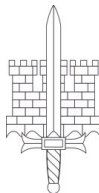
Essays in National Defence

Vesa Kanninen

VESA KANNIAINEN

ESSAYS IN NATIONAL DEFENCE

To be presented, with the permission of the Research Council of National Defence University, for public criticism for the degree of Doctor of Military Sciences in auditorium Itälinnake at the National Defence University, Santahamina, Helsinki, on August 17th 2018 at 12 o'clock.



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ABSTRACT

Background and motivation

For many small countries with a long history of conflicts with a large neighbouring country, the question of national security has a high priority. Alternative survival strategies include a sufficiently strong defence capability in terms of the defence design and quality of defence materiel or, alternatively, a membership in a defence alliance. Such choices should be based on cost/benefit analyses. The urgency of such analyses becomes burning if tensions arise for one reason or another or if the available options change and attract public discussions, or if the safety class of the country has deteriorated.

In Finland, the choice between a military draft (conscription) and an all-volunteer professional army has been the subject of continuous debate over the years. Moreover, as a result of Russia's occupation of Crimea in 2014 and the subsequent Ukraine crisis, tensions also intensified in the Baltic Sea area. After the Cold War, there was a peaceful period in Western and Central Europe. However, subsequent aggressive political tensions grew. As a response both in Finland and in Sweden, the issue of a potential membership in NATO, the North Atlantic Treaty Organization has been at the core of the debate. As a result of increased tension, Sweden has regretted its abolishment of the draft and its demilitarisation of Gotland Island. It has tried coming back to a partial draft army, but with limited success.

The issue of how much to allocate resources to national defence has to do with the valuation of the willingness of the country's citizens concerning the importance of national security. In repeated surveys, such willingness is appreciated by more than 70 per cent of the population in Finland. This is apparently based on the history of the country with repeated aggressions between the Swedish and Russian empires and the attacks by the Soviet Red Army at the beginning of and during World War II.

Research tasks

Analytical views on motives behind countries' fighting have attracted a lot of attention in the theory of conflicts. However, no behavioural theory has been analytically formulated in terms of the risk-taking attitudes of individual soldiers, particularly in a defending army against a larger predator. The current study aimed to produce such an analysis, suggesting a theory of commitment to defend in the spirit of intertemporal altruism across generations. Such an analysis is included as the first article in the current collection. It is extended to study the possibilities of creating deterrence against an attacking army by means of communication and the signaling of the willingness to defend itself. The approach employs game theoretic tools. The second article focuses on

the issue of army design through a draft or is alternatively based on a professional army. The third article derives the mathematical option value for a membership in a defence alliance in terms of a coalition theory. In both of them, the analysis is based on a cost-benefit approach. In both articles, the key analytic concept to start with is the risk classification of a country.

The key building block in setting up the national defence is based on the acquisition of appropriate defence materiel. Two articles in this collection provide multi-stage analytic decision-theoretic approaches for two issues, i.e. offsets and joint procurements. No previous economic theory of offsets is available in the existing literature. The issue is timely, as Finland has launched its plan to replace its current F/A-18 fighters with a new type of fighter in the coming years. Joint procurements in the acquisition of defence material between independent countries make sense as they seem to be economically justified. In reality, few have actually taken place. The fifth article in the current collection attempts to explain why this is probably the case. For example, efforts to jointly carry out the acquisition of the NH90 helicopters among four Nordic countries failed. Moreover, despite the obvious benefits of joint procurements between the small Baltic states, they never appear to take place.

Finally, the cyber technologies appear to provide a new and complementary instrument for conventional armament. In 2010, the world learned about Stuxnet, a malicious computer worm believed to be jointly created by American and Israeli cyber weapon specialists. Experts have been convinced that Stuxnet was meant to sabotage the uranium enrichment facility at Natanz in Iran and its centrifuge operational capacity, but the damage spread to other units, too. It is believed that most of the infected computers worldwide by Stuxnet have been in Iran. The Stuxnet attack is the background for the last article in this collection. It explains why cyber technologies have potentially led to a new era of warfare between hostile countries.

Research methods

The aim of the current study is to address the issues related to factors or decisions that determine the national security in a small country: the willingness to defend, the army design, potential membership in a military coalition, the acquisition of the defence materiel, and the role of cyber capability as a new type of warfare. The approach of the current collection of studies is based on the employment of economic tools and includes economic cost/benefit analyses, mathematical optimisation methods, game-theoretic models, extensions to the Tullock model in contests, and the Nash bargaining approach in arriving at contracts. National security is viewed as a public good and the question is how to incentivise the decision-makers to arrive at the best policies. Tools of information economics are relevant, as a small defending country must try to communicate and signal to a potential predator its commitment to defend.

Analytic economic methods are not that typical in the discussions and debates on national security in our country. One reason may be that the war games in such an approach take place in a fictitious mathematical world. It is hoped, however, that with its theoretical results, the current study is able to deliver a message of the usefulness of economic and mathematical tools for conflict studies. Starting with his works in the 1920s, the game theory was initially developed by the Hungarian mathematical genius, John von Neumann. His focus, however, was on zero-sum games, yet typical confrontations in politics or conflicts are not necessarily characterised by zero-sum games. Instead, the Coase theorem suggests the opposite: a peaceful settlement of issues is Pareto-efficient and should lead to a surplus-maximising win-win outcome. Then, the issue arises as to why a commitment to a no-fight equilibrium is so difficult to obtain in the real world. The subsequent development of game theory has moved in other directions: negotiation, bargaining and signaling under informational restrictions. The pioneering work by Thomas C. Schelling, the Nobel prize winner in economics in 2005, characterised the key elements in war games. In his Nobel prize lecture, he expressed his delight on that the world had been able to live without a nuclear war for over sixty years. The famous lesson stated by the Prussian General von Clausewitz in the 19th century on "...not [taking] the first step without considering the last" is one of the corner stones of the modern dynamic game theory.

The purpose of mathematical models employed in economics is not to say that they represent the real world. The model world is fictitious and it exists only in the brains of the researchers – and in their publications. Their justification arises from their operation as helpful instruments in checking the validity of thinking and of the stated arguments. Human brains make mistakes, but the mathematics does not. The purpose of models is to build into the analysis the key mechanisms to be examined, rather than the whole messy real world. Many aspects are therefore left out on purpose without claiming that they are irrelevant. The purpose instead, is to put the focus on the key mechanisms.

YHTEENVETO

Tutkimuksen tausta ja motivaatio

Monelle pienelle maalle, jonka historiaan sisältyy konflikteja suuremman naapurimaan kanssa, kansallinen turvallisuus on keskeinen haaste. Vaihtoehtoiset selviytymisstrategiat edellyttävät riittävän puolustuskyvyn rakentamista, riittävän puolustuskaluston hankintaa sekä mahdollisesti jäsenyyttä puolustusliitossa. Kaikkien näiden valintojen tulisi perustua hyöty-kustannusanalyyseihin. Sellaisten analyysien tarve korostuu, jos jännitys lähialueilla syystä tai toisesta kiristyy ja jos maan riskiluokka heikkenee.

Suomessa on pitkään käyty keskustelua yleisen asevelvollisuuden ja vapaaehtoisen asepalveluksen paremmuudesta. Venäjä liitti Krimin itseensä vuonna 2014. Tuolloin käynnistynyt Ukrainan kriisi on lisännyt jännitystä myös Itämeren alueella. Kylmän sodan jälkeen Länsi- ja Keski-Euroopassa vallitsi rauhan kausi. Tilanteen kiristyminen on johtanut sekä Suomessa että Ruotsissa keskusteluun jäsenyyden hakemisesta puolustusliitto NATO:oon. Ruotsi on niin ikään katunut päätöstään luopua yleisestä asevelvollisuudesta ja Gotlannin saaren demilitarisoinnista. Se on pyrkinyt palauttamaan tietynasteisen asevelvollisuuden, mutta ei ole siinä onnistunut.

Kuinka paljon kansalliseen puolustukseen tulisi sijoittaa yhteiskunnan resursseja, riippuu siitä, kuinka tärkeäksi kansallinen turvallisuus kansalaisten keskuudessa koetaan. Kyselyjen perusteella maanpuolustustahto on Suomessa korkea. Tämä on varmaankin yhteydessä maan historiaan. Suomen alue joutui toistuvien Ruotsin ja Venäjän välisten sotien näyttämöksi. Toinen selitys korkealle maanpuolustustahdolle löytyy Neuvostoliiton aggressiosta toisen maailmansodan aikana.

Tutkimustehtävät

Konfliktien tutkimuksessa on varsin paljon arvioitu syitä ja motiiveja sotimiseksi. Mikään käyttäytymisteoria ei kuitenkaan ole tuottanut analyttistä esitystä yksittäisen sotilaan valmiudelle ottaa vastuuta puolustustehtävästä ja siihen liittyvästä riskistä, kun on kyse puolustautumisesta suurempaa uhkaajaa vastaan. Käsillä olevan tutkielman ensimmäinen esse tuottaa tätä koskevan analyysin. Se rakentuu ajatukselle sukupolvien ylittävästä altruistisesta motiivista. Sen pohjalta esseessä kehitetään analyysi siitä, miten puolustautuva maa voi omilla puolustusratkaisuillaan pyrkiä luomaan riittävän kynnyksen potentiaalisen vihollisen hyökkäyksen ehkäisemiseksi. Yksi osa tätä strategiaa on, että puolustaja samalla pyrkii kommunikoimaan viholliselle valmiutensa ja halunsa puolustautua. Analyysi hyödyntää peliteoriaa. Toisessa esseessä esitetään vertailu yleisen asevelvollisuuden ja vapaaehtoisen asepalveluksen välillä. Kriteerinä on kansantalouden hyvinvointi, jossa tulojen lisäksi toisena tekijänä on

kansallinen turvallisuus. Kolmas essee pureutuu kysymykseen mahdollisesta jäsenyydestä puolustusliitossa ja johtaa tähän liittyvän option matemaattisen arvon. Molemmat rakentuvat sen ajatuksen varaan, että eri maat ovat riskiluokaltaan eri asemassa.

Kansallisen turvallisuuden vahvistamisessa myös oikea puolustusvälineistö on avainasemassa. Kaksi seuraavaa essetä käsittelevät tähän liittyvää päätösteoriaa niin sanottujen vastakauppojen sekä yhteishankintojen muodossa. Huolimatta laajasta kirjallisuudesta vastakauppojen talousteoriaa ei ole ollut olemassa. Neljännessä esseessä luodaan tällainen teoria. Vaikka yhteishankinnat näyttävät taloudellisesti perustelluilta, niitä tapahtuu kuitenkin huomattavan vähän. Viides essee tarjoaa useita selityksiä sille, miksi näin on asianlaita. Esimerkiksi yhteispohjoismainen kopterihankinta ei toteutunut ja useat suunnitellut onnistumattomasti peruttu. Myöskään pienet Baltian maat eivät jostain syystä tee yhteisiä kalustohankintoja.

Kyberaikakaudella perinteinen aseistus on saanut kilpailijan ja sodankäynti samalla uuden instrumentin. Vuonna 2010 maailman tietoon tuli Stuxnet, tahallinen tietokonevirus, jonka uskottiin olleen amerikkalaisten ja israelilaisten specialistien tuottama. Uskotaan, että sen tarkoitus oli sabotoida Natanzin uraanirikastamoa ja sen kapasiteettia Iranissa, mutta sen tuho vaikutus levisi muihinkin yksikköihin. Tämä tapahtumaketju on viimeisen esseen aihe. Siinä pyritään selittämään, miten kyberteknologia on johtanut uuden sodankäynnin aikakauden vihollisvaltioiden välillä.

Tutkimusmenetelmät

Käsillä olevan tutkielman tarkoitus on pureutua kansallisen turvallisuuden selitystekijöihin pienessä maassa: puolustushalu, asepalveluksen valinta, mahdollinen jäsenyys sotilasliitossa, kalustohankinnat ja kybersodan rooli. Tutkielma hyödyntää taloustieteen tutkimusvälineistöä: hyötykustannusanalyysia, matemaattisia optimointimenetelmiä, peliteoriaa, niin sanotun Tullock-mallin laajennuksia konfliktien teoriassa ja Nashin neuvotteluteoriaa. Kansallinen turvallisuus nähdään julkishyödykkeenä ja kysymys kuuluu, mitkä ovat oikeat ja siten kansakunnalle parhaat päätökset. Informaation talousteorian välineet osoittautuvat tärkeiksi, kun on tarve analysoida kysymystä siitä, miten kommunikoida potentiaaliselle viholliselle maan puolustustahto.

Kansallista turvallisuutta koskevissa väittelyissä taloustieteen välineistö ei ole ollut Suomessa laajalemmmin käytössä. Selitys voi löytyä siitä, että matemaattiset analyysit toteutuvat kuvitteellisissa matemaattisen maailmassa. On kuitenkin toivottavaa, että tämän tutkielman tulosten myötä taloustieteellisten ja matemaattisten välineiden arvo tutkimukselle tulee ilmeiseksi. Peliteorian kehittäjän alun perin unkarilainen matematiikan nero, John von Neumann. Hänen painopisteensä oli nollasummapeleissä. Kuitenkaan useimpia ristiriitaitilanteita ei ole syytä aidosti nähdä nollasummapeleinä. Niinpä Coasen teoreema viestittää

siitä, että rauhanomainen konfliktien purkaminen neuvottelemalla edustaa Pareto-tehokkuuteen ja ylijäämän maksimoivaan lopputulokseen johtavaa ratkaisua. Tästä näkökulmasta kuitenkin avautuu kysymys: miksi reaali maailmassa niin usein jää toteutumatta tasapaino, jossa ei sodita?

Sittemmin peliteoria on kehittynyt suuntaan, jossa tarkastellaan neuvottelua ja kommunikointia. Sotien ja konfliktien teorian pioneeri, Thomas C. Schelling osoittautui töillään vuoden 2005 taloustieteen Nobel-palkinnon arvoiseksi tutkijaksi. Nobel-luennossaan hän ilmaisi tyytyväisyytensä siihen, että maailma oli onnistunut elämään ilman ydinasotaa yli 60 vuotta. 1800-luvun preussilaisen kenraalin von Clausewitzin sanoin: ”Ensimmäistä askelta ei tulisi ottaa ennen, kuin on selvittänyt, mikä on se viimeinen askel”. Tämä viisaus on dynaamisen peliteorian kulmakiviä.

Matemaattisiin analyysivälineisiin tukeutuminen ei ole itsetarkoitus. Tarkoitus ei ole väittää, että ne edustavat reaali maailmaa. Mallimaailma on kuvitteellinen ja se on olemassa vain tutkijoiden aivoissa – ja heidän tieteellisissä julkaisuissaan. Niiden käyttämisen oikeutus perustuu siihen, että ne toimivat tutkijan ajattelun, logiikan ja esitettyjen argumenttien validiuden testinä. Ihmisen aivot tekevät virheitä, matematiikka ei. Tarkoitus aina on, että malleihin sisällytetään vain tutkittavan kysymyksen kannalta kaikkein oleelliset mekanismit äärimmäisen monimutkaisen reaali maailman asemesta. Mallit ovat yksinkertaisuuksia ja monet reaali maailman elementit jätetään niistä pois, ei siksi, että ne olisivat irrelevantteja, vaan siksi, että tarkoitus on keskittyä kaikkein oleellisimpaan.

PREFACE AND ACKNOWLEDGEMENTS

The idea of reporting the results of the current studies as a dissertation evolved a few years ago as I was retiring as Professor of Economics at the University of Helsinki. I made an enquiry about such an option with Professor Juha Mäkinen from FNDU, who strongly encouraged me. Subsequently, Professor Juha-Matti Lehtonen suggested two timely topics to be included in the collection. I am happy to have had the chance to work with him on those issues of great relevance, and I am grateful to him for accepting my work in the dissertation program at FNDU. He has strongly supported this research throughout the process.

I wrote two papers in this collection with Dr Staffan Ringbom from Hanken. I am grateful for the cooperation with him. During the process, I proposed the CESifo research unit based at the University of Munich to organise an international workshop titled “*The Economics of Peace and War*”. This indeed took place in Venice in 2016. I was happy to work with Professor Panu Poutvaara for the workshop, which attracted a number of competent scientists in the field of conflict studies. CESifo Economic Studies was able to publish a subset of the papers presented through a strict refereeing process. I have given several lectures and speeches on the topics of the current package and I am indebted to the audiences’ helpful feedback. I am also grateful to the official pre-examiners, Professors Pauli Murto and Hannu Salonen for their evaluations of the dissertation as the official pre-examiners.

Of six articles in the current dissertation, five were reviewed by highly competent referees. The last one is still in a process, but I have included a discussion paper version of it in the thesis. I am grateful to the journals for giving me permission to include these articles in the dissertation. For copyright reasons, the dissertation is not available online while the published articles are found on their web sites.

During my research efforts, my wife Pirjo has been an active discussant and an opponent in our “home seminar”, in the summer cottage, and while traveling. I am most grateful to her. Her input as a critical judge was especially important in the first article in this collection. We share the concerns of the importance of national security in our country. In her youth, female participation in the draft was not possible, which she has regretted *ex post*. Subsequently, however, she was employed by the national defence organisations. It turned out that she is capable of understanding and arguing about the research issues which I am working on. She dislikes (read: hates) my formulas and she keeps saying that she is capable of making her point without algebra.

For several years, I have had the opportunity to participate with my wife in a hiking group with our friends to the Alps. During those long hikes in the mountains, many topics have been analysed both during the hiking effort and

while having a pause with a Weissbier or with a drop of Obstler. Especially the discussions on national security issues with Seppo Lamminen, Pertti Räsänen and Matti Virpiaro have been the most fruitful not forgetting their always active wives, Allu, Anja and Kati. I express my gratitude to all of them for those discussions, and I am looking forward to the next “mountain seminar”.

Helsinki 10.06.2018

Vesa Kanninen, Professor of Economics, Emeritus (University of Helsinki)

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LIST OF APPENDED PAPERS

This thesis by Vesa Kanniainen comprises a summary and the following six publications.

- I. Defence Commitment in Deterrence of War
Vesa Kanniainen
CEsifo Economic Studies, (2018).
DOI: 10.1093/cesifo/ify001

- II. Security Gradient and National Defense – The Optimal Choice between a Draft Army and a Professional Army
Vesa Kanniainen and Staffan Ringbom
Defence and Peace Economics, 29(3), 2018,247-267. DOI:
<http://dx.doi.org/10.1080/10242694.2016.1144898>

- III. The Option Value of Membership in a Defence Alliance
Vesa Kanniainen and Staffan Ringbom
FinanzArchiv, 73(4), 2017, 382-410.
DOI: <https://doi.org/10.1628/001522117X15052857415053>

- IV. Offset Contracts as an Insurance Device in Building the National Defence
Vesa Kanniainen and Juha-Matti Lehtonen
Defence and Peace Economics,
DOI: <https://doi.org/10.1080/10242694.2017.1335366>

- V. Joint Procurements in Building National Defence: Why Are There So Few?
Vesa Kanniainen and Juha-Matti Lehtonen
Discussion Paper No. 427 of HECER, Helsinki Center of Economic Research, March 2018,
Defence and Peace Economics, (under heading ”Collective Procurement in Building National Defence: Why Are There So Few”)
DOI: <https://doi.org/10.1080/10242694.2018.1471320>

- VI. Cyber Technology and Arms Race
Vesa Kanniainen
HECER, Helsinki Center of Economic Research, Discussion Paper N:o 424, February 2018.

The author's contributions to the respective appended papers have been:

- I. The sole work of the author, with valuable and acknowledged support from the colleagues.
- II. Most of the research design and writing.
- III. Most of the research design and writing.
- IV. Part of the research design, the technical analysis, part of the writing.
- V. Part of the research design, the technical analysis, part of the writing.
- VI. The sole work of the author, with valuable and acknowledged support from the colleagues.

1

CONFLICTS: HISTORY AND OVERVIEW

1.1. Violence and life

Human history is witness to violence and fights between tribes, societies, and nations. The reasons and motives for violence are many and have been the subject of a large number of studies in various disciplines including military studies, psychology, evolutionary studies, social sciences and economics. No single explanation can emerge. The motives of wars include psychological, biological, economic and geopolitical reasons.¹ In contrast to conventional wars, the warfare in modern times has also developed into new destructive instruments like chemical or biological strikes, terrorism, and more recently to cyber attacks, information war, or a hybrid war that combines several elements. When the military capacities between those in conflict deviate substantially, a war is an asymmetric one. There can be a predator and a victim. For one of the parties, it is a matter of making an attack and for the other one a defence war.²

It should be pointed out that wars should not exist in equilibrium: according to the Coase theorem, the conflicting partners could peacefully negotiate, avoiding the cost of war and reaching a surplus-maximizing outcome. As we repeatedly see wars, the conditions for the Coase theorem appear not to be valid. The key question then arises: why is this the case? In the current study, possible answers are provided in two essays (Essay 1 and Essay 6). In economic terms, wars represent non-Paretian and destructive mechanisms of competition for power, resources, or prestige. Peaceful periods in the human history have been repeatedly followed by aggressive fights between nations and their armies. Based on the extensive historical data set, however, Harvard psychology Professor Steven Pinker has provided the provocative proposition

¹ The survey by Levy (1989), for example, has 800 references. The bioeconomic causes of war have been addressed by Hirshleifer (1998) stating that "... the ultimate motives for fighting are food and sex, the essential elements of reproductive success... humans seek food and sex directly, but also indirectly via dominance and prestige... In modern times... intangible goals such as prestige, dominance, and respect ... remain with us as the continuing causes of war." An interesting recent work by Iyigun, Nunn and Qian (2017) has found a link between the increase in the agricultural productivity and the reduction of conflicts for roughly two centuries after potatoes were introduced from South America to the Old World.

² Excellent surveys of the economic research on wars have been provided by *the Handbook of Defense Economics*, 1 and 2, ed. by Sandler and Hartley (1995, 2007), Jackson and Morelli (2009), Garfinkel and Skaperdas (2012) and Baliga and Sjöström (2013).

that the evolution of the societies and the world have made humans more peaceful (Pinker, 2011). His data suggest that relative to the world population, fewer people die in wars in modern times than in the history.³ His book led to a sharp intellectual confrontation with Cirillo and Taleb (2016), who questioned his statistics. A shocking record from peaceful Nordic countries reveals that few countries have fought more against each other than Sweden, Denmark and Norway: after Gustav Vasa came to power in 1523, there were eleven fights among them over 300 years.

1.2. Military expenditures in today's world

Countries allocate substantial resources to their military capacities; their defence budgets may even amount to several per cent of the GDP. The costs and benefits of the military, however, are not measured by the size of their military budgets but rather by the welfare cost of taxation and the security effect of the army as a public good. The international markets for defence material are well-organised and rather competitive though the political interest conflicts have an important role to play there.⁴

The relationship between military expenditures and economic growth has been an issue for quite some time. In the literature, there are several channels identified that may simultaneously produce positive and negative impacts of military expenditures on economic growth. In the end, one would expect that the relationship is negative as consumption and national security represent competing aims of resource allocation. A meta analysis on the controversy of the effects of wars was carried out by Alptekin and Levine (2012). They reviewed 32 empirical studies with 169 estimates of the effect of military expenditure on economic growth. They found that actually the hypothesis of a negative military expenditure-growth relationship is not supported for both

³ The worst event in terms of human suffering by fights took place in China, in the rebellion and the civil war of An Lushan in 755-763 when 36 million people, 17 per cent of the world population, died. During the wars of Ghenghis Khan in the late 12th and early 13th centuries, 40 million died amounting to 1 per cent of the world population. During World War II, 55 million people died amounting to 2,2 of the world population. Referring to the book by Royle (1989), Hirshleifer (1998) notices that Genghis Khan (1162-1227) is supposed to have said: "The greatest pleasure is to vanquish your enemies, to chase them before you, to rob them of their wealth, to see their near and dear bathed in tears, to ride their horses and sleep on the white bellies of their wives and daughters". In his monumental book Pinker argues that the mechanisms of reason, empathy, the moral sense, and self-control have made the world safer. In tribe societies, empathy was more concentrated on one's own kin and relatives while modern humans are able to feel empathy towards strangers, too. A similar view can be found in Seabright (2010). Moreover, when the state has monopolised the violence, the use of one's own hand is no more profitable. Economic development has made other people more valuable when alive than dead and the cooperation has replaced anarchy. The developed countries do not often fight against each other perhaps because the mutual costs of war are so enormous.

⁴ Military Balance is the key report of the military expenditures in the world.

LDSs and in general while a positive effect of military expenditure on economic growth is supported for developed countries. One could speculate that the finding may perhaps be explained at least partly by the fact that the development of new technologies and the associated military innovations have been driving the technology frontier even faster than the innovation in purely civil areas.⁵

1.3. Is the Cold War back?

After World War II, Western Europe has been a continent of peaceful development. The end of the Cold War in the early 1990s increased optimism concerning the future. The German reunification and the extension of NATO membership to most of the former Soviet allies in Europe and to the Baltic states, led to optimism about a peaceful development within Europe. In the aftermath, however, the furious civil wars in the former Yugoslavia shook such optimism. The Kosovo crisis led to military intervention by the NATO air forces. The Russian trauma associated with the collapse of the Soviet Union in 1991 led to a new confrontation, first in Georgia and subsequently in Ukraine.⁶ Russia released a new military doctrine on December 26, 2014, to demonstrate its position in the world. NATO has strengthened its presence in the Baltic states and in Poland. In a sense, the Cold War is back in Europe.

1.4. Terrorism – war without frontiers

Outside Europe, terror attacks have been common, with the purpose of causing damage in terms of lives lost and fear among people. Their effect is much bigger than the number of victims who die. Terrorist attacks have arrived to Europe in recent years, with militant islamists targeting people in the cities of Great Britain, France, Belgium, Germany, Russia, Sweden and Finland. It is apparently legitimate to trace the roots of the most recent wave terrorism in Europe to the attack initiated by American and British leaders against Iraq in 2003. On terrorism, an early reference is Sandler (2005) while Carceles and Tauman (2011) represents a more recent one. The literature on terrorism is expanding fast, but the literature on cyber war and hybrid war is yet to come.

1.5. War as a strategic or political instrument: Sun, von Clausewitz, Machiavelli

Early views on warfare go back to ancient times. Among the famous thinker, a Chinese general Sun Tzu, living around 500 B.C., appears as the earliest one. The descriptions within *The Prince* by Machiavelli have the general theme of

⁵ It is sad to state that many human innovations – gunpowder, radar, antibiotics - have been linked to military aims rather than for the benefit of the civil sectors of society.

⁶ The Georgian War was actually initiated by the Georgian leaders, not by Russia! The political reasons for the war in Ukraine are the subject of some dispute.

accepting that the aims of princes—such as glory and survival—can justify the use of immoral means to achieve those ends. For him, the two most essential foundations for any state, whether old or new, are sound laws and strong military forces. A self-sufficient prince is one who can meet any enemy on the battlefield. He should be "armed" with his own army. Machiavelli stood strongly against the use of mercenaries, believing that they are useless for a ruler because they are undisciplined, cowardly, and without any loyalty, being motivated only by money. Machiavelli attributed the Italian city states' weakness to their reliance on mercenary armies.

The most influential writer of the 19th century on warfare was Prussian General von Clausewitz. He is famous primarily as a military theorist interested in the examination of war, utilizing the campaigns of Frederick the Great and Napoleon as the frames of reference to his work. He wrote a careful, systematic, philosophical examination of war in all its aspects. The result was his principal work, *On War*, a major work on the philosophy of war. He stressed the dialectical interaction of diverse factors, noting how unexpected developments unfold in the face of incomplete, dubious, and often completely erroneous information and high levels of fear, doubt, and excitement. Often stated as the words of von Clausewitz: "War is thus an act of force to compel our enemy to do our will." The second, often treated as von Clausewitz's bottom line, "War is merely the continuation of policy by other means." The well-known citation from von Clausewitz (cf. Holmes (2007)) is given (p. 584) as; "the clearer appear the connections between its separate actions, and the more imperative the need not to take the first step without considering the last". Such a requirement of foresight essentially aligns with the message of the modern dynamic game theory.

1.6. Picking up the right game theory: John von Neumann vs Thomas C. Schelling

With the introduction of modern research methods developed in mathematics, economics, and evolutionary biology, conflict studies have provided insights into the motives, incentives, processes and mechanisms of conflicts. Analyses today most often employ game-theoretic approaches. While John von Neumann, the founder of zero-sum games spoke for a nuclear attack by the US on the Soviet Union, Thomas C. Schelling had the opposite idea. For him, the world is not a platform of zero-sum games but rather a network of non-cooperative actions with multiple equilibria with win-win strategies available.⁷

The economic analysis of conflicts was introduced by Schelling (1960, 1965), the subsequent Nobel prize winner in economics. Though not fully formal,

⁷ Those sharply opposite views by von Neumann and Schelling are documented in Harford (2008) and were relevant in the tension between the USA and the Soviet Union.

his analyses were written in the spirit of non-zero-sum game theory. Schelling considered a conflict from the point of view of rational players under informational restrictions. In such a setting, the credibility of statements and actions, the commitment, becomes the key concern for the participants in a mutual confrontation. The sensitive equilibrium is defined in terms of the expectations of the expectations of the opponent concerning the expectations of the opponent concerning the expectations... and so forth. Schelling was writing in an era when both superpowers had accumulated huge reserves of nuclear weapons.⁸

After Schelling, the approaches and solution concepts of game theory were applied in the context of the theory of conflicts. A combination of a political economy and game theoretic view in the issues of peace and war was provided by de Mesquita (2006).

1.7. Who is the likely winner in warfare?

When a conflict turns into war, the probability of the victory is determined by the relative strength of those involved. Tullock (1967, 1980) formalised this idea which has subsequently been studied by a number of authors including Hirshleifer (1991), Garfinkel and Skaperdas (2007), Konrad (2009) and Chowdhury and Sheremeta (2010). Several refinements have been suggested in terms of contest success function, which is the key analytic tool in the theory of war games today.⁹

1.8. Alliance formation

The basic model of controlling conflicts through an alliance formation was developed by Olson and Zeckhauser (1966) and extended subsequently by Sandler and Hartley (2001) and Ray and Vohra (1999). Free riding turned out to be the key incentive issue in the provision of international public goods. The distinction between an offence and a defence war was earlier discussed by Lynn-Jones (1995) (see also Arce, Kovenock and Robertson, 2012).

1.9. Arms race

Baliga and Sjöström (2004) showed the conditions under which the unique Bayesian-Nash equilibrium between two players involves an arms race for sure. Grossman (2004, 2013) illustrated how the ability to negotiate a peaceful settlement depends on the divisibility of the outcome of the dispute, on the effectiveness of the fortifications and counterattacks and on the permanence of the outcome. Jacobsson (2009) showed how the cycles of war and peace

⁸ A recommended evaluation of Schelling's work is Myerson (2009).

⁹ It should be pointed out that the static Tullock model resembles the two-equation dynamic differential equation system developed by Frederic Lanchester during World War I to show which of the two armies will win a war, cf. Davis (1995).

may arise in a model where the arming decisions and the decision whether to go to war takes place in a later stage. Spolaore (2009) reviewed the economics approach to conflicts and national borders and Alesina and Spolaore (2005) studied the relationship between international conflict and the size distribution of countries in a model in which both peaceful bargaining and non-peaceful confrontations are possible. McQuire (2010) studied how economic productivity and trade, military technology and strategy, and political economy of governance can be combined to determine a country's choice between peaceful trade and investment vs. predation and conquest of others. The observations of provocative actions led Baliga and Sjöström (2012) to analyse the effect of hawkish and dovish extremist strategies on the likelihood of a conflict.

1.10 Towards empirical testig

The modern development of research area extensively employs the methods of the game theory, the theory of incentives and information theory. As the data sources on various social developments have been substantially improved over the decades, high-quality empirical work on conflicts based on econometric methods, including terrorism and civil wars has become possible and has provided a deeper understanding about the processes involved. Hwang (2012), for example, studied conflict technology and contest success functions estimating the elasticity of augmentation using actual battle data including 17th-century European battles, as well as those from World War II.

2

ARTICLES IN THIS COLLECTION: THE RESEARCH ISSUES AND SUMMARY OF THE MAIN RESULTS

2.1. Defence Commitment and Deterrence in the Theory of War

CESifo Economic Studies, (2018), 1-22, doi: 10.1093/cesifo/ify001, published by Oxford University Press.

Background

The regularities and motives of war have been the subject of a large body of military studies. In the current paper, a particular type of war is under focus: asymmetric warfare between two countries with different military strengths. Large empires in particular, tend to control and even attack on their smaller neighbors. This paper studies an asymmetric war in the spirit of the predator-victim framework.

Over the course of history, no common motivation for war in general is available. Political science views appear to acknowledge the geopolitical factors. Economists have mostly considered wars as contests, largely neglecting other motivations for warfare. Motivational determinants apparently need to be integrated into the theory in a deeper and more consistent way to explain such behaviour. The paper introduces an economic approach building on the biological and evolutionary foundation. A unique feature of the model is that soldiers choose how much warfighting risk to take on themselves as a building block for the theory of defence and deterrence. The paper introduces a well-defined intergenerational altruistic preference structure of individual fighters in conditions where the risk of death is the choice variable. The survival probability of the offspring is part of the altruistic preference structure of the individual soldiers. To further motivate such a research agenda, the paper recalls that it is indeed the fight of the current generation for the survival of its offspring that is the fundamental mechanism in all nature. This concerns all living creatures, even including plants.

The literature on military studies justifies the view that motivational reasons for war, conflict, and aggression are many. The soldiers can care about a country winning the war for a number of reasons. Such a psychoanalytic view was advanced by Fornari (1975), who claimed that sacrifice is the essence of war: it translates into the willingness of humans to die for their country. Of course,

the paper does not challenge the literature of the military studies or of other motives. Our paper suggests that when it is a matter of survival for a victim to resist an attack by a stronger predator, the fundamental altruistic motives may become relevant.

Such a concept is supported by many examples. In 480 BC, the vastly outnumbered Greeks held off the Persians for seven days in the battle at the pass of Thermopylae in the most remarkable defence battle in history. In 1565, 700 Johannite knights and 8000 Maltese soldiers successfully defended Malta island against an Ottomans attack by an army of 40 000, more than four times greater. The Vietkong guerrillas were able to beat the more advanced US army during the 1960s. In the three-and-a-half-month Winter War of 1939, the Finnish army stopped Stalin's Red Army (though it was three times stronger), and did so for the second time in 1944 in the Battle of Tali-Ihantala (with the Red Army having four times the superior power), the largest-ever battle in the Nordic countries. Moreover, though it was five times larger, the Russian Red Army was defeated when it attacked the smaller German-Estonian defence forces at the Siltamäe battles in July and August 1944 causing a substantial loss of men.

Research questions and approach

Two questions are raised:

- Is it possible to formulate a theory of an individual soldier as a group member on a battle field?
- What are the implications for the optimal defence policy in a predator-victim model of war with asymmetric information about the commitment of the soldiers in providing a defence effort and about the perceived cost of war?

The paper introduces first an analysis of the risk-taking and commitment of an individual soldier in providing the defence effort in a predator-victim model. Each individual soldier is risk averse and is assumed to face the risk of death resulting both from exogenous reasons beyond his control and from his own choice in a conflict situation. It is then assumed that the risky operations call for collective actions and group cohesion. In particular, the commitment of providing a risky effort is assumed to arise from the intertemporally altruistic preference towards the offspring. The soldier values both his own life and the life of his child. The defence effort of the soldiers results in an externality on the safety of the civilians. An individual soldier, however, is assumed to value the externality on the life of his child alone, not on the life of co-citizens and their children. The paper shows that in the commitment equilibrium, there is no underprovision of effort. Moreover, though the created national security is a non-excludable public good, the civilians who free ride on the

externality are financing its production through their tax liability. When building its national security, a potential victim hopes to communicate to the predator that it is committed to defending itself, by investing ex ante in defence. Under informational asymmetries, however, it may be difficult to convincingly communicate such a commitment.

Results

The main results of the paper are as follows. In the commitment equilibrium, intergenerational altruism can explain why the defending army fights hard, and even more so when the predator's military capacity is large. Small armies in particular fight harder than large armies. The implications for deterrence and defence policy are shown to be important. Indeed, the second set of results concerns the optimal size of the army. In the absence of informational constraints, there is a unique army size for deterrence. Under informational restrictions, a pooling equilibrium may exist where a victim with strong intergenerational altruism overinvests in its army while the victim with a more limited intergenerational altruism free rides on the information gap of the predator building a smaller army. Conditions for the existence of a separating equilibrium are established in terms of the cost of war. A victim with a high perceived cost of war tends to be willing to build a large army as a costly signal with the purpose of being differentiated from a victim with a lower perceived cost of war. It turns out that the optimal defence policy need not satisfy the deterrence requirement, but rather the optimal army size is determined by the elasticities of the utility with respect to the tax cost and the probability of victory relative to the army size. The case of separating equilibrium helps to explain why wars exist in equilibrium.

2.2. Security Gradient and National Defense – The Optimal Choice between a Draft Army and a Professional Army

Defence and Peace Economics, 2018, 29(3), 247-267, published online 2016, March 1, doi.org/10.1080/10242694.2016.1144898, published by Taylor and Francis, co-author: Staffan Ringbom.

Background

For each nation, the national security represents a public good. There are various ways of providing it. In 1970, the President's Commission on An All-Volunteer Armed Force (Gates Commission) launched its by now the classic analysis with the aim of eliminating the draft in the USA. The message of the Commission was well-taken by President Richard Nixon: the draft was replaced by an all-volunteer substitute. The arguments put forward by the

Commission were built both on the concerns of inefficiency and inequity characterized by the draft. One of the influential members of the Commission, Milton Friedman had strongly argued against the US draft since 1967 (Friedman, 1967). The attitudes were also influenced by the catastrophic Vietnam war. Many countries in particular in the Western Europe have followed the US lead, most recently Sweden (2010) and Germany (2011).

The widely-held view among the economic profession appears to be that unlike the draft, the professional army is cost-efficient (see Warner and Asch (2001) for a review). The paper by Asch et al. (2007) suggests that there will be a force size below which volunteer forces are cheaper and beyond which a volunteer system is more costly. Their paper also provides an extensive overview on the empirics of the US manpower, the occupational choice, the optimal mix of manpower and other inputs to military readiness and the role of reserves. The implications of the draft as a hidden tax were formally analyzed by Poutvaara and Wagener (2007). They introduced a striking proposition that the utility level in the steady state of an economy with a draft system *always* falls short of the utility level of an economy with a professional army. This conclusion is based on the following crowding-out mechanism: the effort into human capital formation through education and, consequently, the output and the consumption as well as the maximally obtainable utility level with a draft system always falls short of the utility level of an economy with a professional army. As both solutions to the military delay the education investment for the young involved, the individuals entering the professional army with a market salary welcome a positive tax due to the discounting benefit. They are paid for their service during the early stage of their life-cycle. Though they subsequently are taxed on their civil income to finance the next generation of the professional army they welcome such an intergenerational transfer. However, their interest is time-inconsistent: when old, they would prefer not to pay the tax. Thus, there is a built-in conflict between the generations in the professional army.

The Poutvaara-Wagener -result is derived in a context where the social welfare criterion fails to capture the proper valuation of national security as a public good. Their model abstracts from the trade-off between the consumption of the market output as a private good and national security as a public good and appears valid only in a world with everlasting peace. It should be noticed that the empirical evidence has widely supported their conclusion.

Research questions and approach

Several questions are raised:

- Is it possible to reproduce the Poutvaara-Wagener -result in a model with an explicit social welfare function and national security as a public good?
- Why are there countries that do not follow the cost-efficient army design based on an all-volunteer army?
- As the economic tools of public economics today are more advanced than they were in the early 1970s when the Gates Commission launched its report, do the new tools help to provide some new perspectives?

The current paper provides a new perspective into the issue of an optimal approach to the optimal design of national security. The need for such an analysis arises for two reasons. One is empirical, one is theoretical. From the empirical point of view, there are countries which persistently appear not to follow the US lead of an all-volunteer armed force. Those countries include Israel in particular but also some European countries (Finland, Austria, Switzerland, Norway, Denmark, Estonia, Greece, Ukraine, Belarus, Russia and Turkey). These cases suggest that the US solution may not be universally optimal. Indeed, in Israel young men are servicing the security of the country for three years and the females for 21 months. Moreover, her defense budget amounts to 7 per cent of GDP. In Finland, the polls suggest that 72 per cent of the population favors the draft in the national defense. In Austria, the corresponding figure is 60 per cent. In the 2013 referendum in Switzerland, 73 per cent of people stood behind the draft rejecting the professional army. The European countries which have abolished the draft have found another solution on their national security: relying on NATO as a joint alliance.

There is also a theoretical reason for reconsideration the issue: the economic tools of public economic are today more advanced than they were in the early 1970s when the Gates Commission launched its report.

Our modeling approach differs from that of Poutvaara and Wagener (2007). They run the comparison between the draft army and the professional army by assuming that the military output is given, and that it equals the size of the active army. In our paper, we introduce explicitly the national security as a public good which needs to be produced. A draft and a tax-financed profes-

sional army are alternative institutional arrangements to address the problem of security design. We identify countries in terms of their risk class in the face of an outside threat. On the way towards such an analysis, we however first reconsider the discounting argument. The draft indeed represents an implicit tax. However, as it is well-understood, the citizens of a country with an all-volunteer army face another tax, an income tax, say. What this suggests is that from the efficiency point of view, the country with an all-volunteer army faces a double distortion, a tax on education and a tax on income required to service the military. Consequently, the discounting benefit associated with the pay to the military should be balanced against the welfare loss.

Results

The paper reports two major results. What we find is that in the utility comparison, the Poutvaara-Wagener -result holds. At the equilibrium, the benefit of the young today equals the discounted tax cost to be paid subsequently and accompanied with the lower education and civil wage. This is our first main result. Moreover, those who outsource the military service to the professionals, are able to raise their education effort which enhances the national value-added. This implies that the rewards on the military and the civilians become differentiated in the way which we show below. There is a utility-maximizing positive tax rate on old to finance the service of the young. However, even in that case it is utility-increasing to pay the young (draftees) an intergenerational transfer, but a low one! Subsequently, we ask by how much the citizens of a country in a particular risk class are willing to pay as an insurance against an outside threat. This is an optimal tax problem which we state a trade-off between an income (wealth) effect and the security effect. We arrive at what we call *a security gradient* along which the countries can be located in terms of their security index. The size of the reserve and its quality determining the defense capacity qualify the optimal choice between the draft and the professional army. This is our second main result. Our numerical simulations illustrate the trade-off along the security gradient showing that above a critical risk class of countries, it is the draft which strictly dominates while for countries in a lower risk class, it is the professional army which dominates.

As an illustration of our security gradient, think of Vatican with no outside threat and no military army, The Republic Uzupis with an army of 11 soldiers¹⁰, or Monaco with a professional army of roughly 200 soldiers. It would

¹⁰ This republic locates in Vilnius of Lithuania declared itself an independent republic in 1997. No government has recognized its independence.

certainly be inefficient to have a draft in those cases. Think then about Israel, a country surrounded by a number of enemies. It could not handle its security unless based on the draft. The USA is a safe country in the sense that no enemy can conquer its territory. It does not need a draft to protect its boundaries. It needs professionals to avoid another Pearl Harbor and the threat from missiles, like during the Cuban crisis. Not the same with Finland. Her collective memory dates back to the 14th century and extends over the subsequent centuries with repeated wars between her Eastern neighbor, Russia, and Sweden, with Finland being located between those countries.

2.3. The Option Value of Membership in a Defence Alliance

FinanzArchiv, 2017, 73(4), 1-20, published by Mohr Siebeck, co-author: Staffan Ringbom.

Background

The recent escalation of military tension in the Baltic Sea area has led to enhanced uncertainty about national security within the countries located there. The adverse development can be traced to military operations in early 2014. In response to the revolution in Ukraine, Russia incorporated the Crimean Peninsula into itself. The conflict intensified into military hostilities in eastern Ukraine, resulting in economic sanctions against Russia introduced by the West. Concerns have been expressed about the deterioration of the safety-class of countries in the area, particularly of the small Baltic NATO members, Poland, and the non-member countries Sweden and Finland. Sweden gave up its infantry in 2010, and it has since been unable to rebuild a professional army. Sweden plans to return to the draft, at least partially, and to reestablish its former military base on Gotland Island after a targeted training attack by Russia with its air force carrying nuclear weapons. Both Sweden and Finland have subsequently signed what is called a “host country” agreement with NATO, yet without the protection provided by Article 5 for full members. Membership in NATO, formed after the Second World War in 1949 as a joint defense alliance, indeed appears as a natural insurance option. It is puzzling that the membership option has not been exercised in those countries, and the current paper asks why.

Research questions and approach

Several issues arise:

- How could countries with a low safety class optimally respond to the increased tension?
- How is the option value of membership determined?
- Under what conditions is it optimal to abstain from the membership?
- What size will a coalition become in a coalition equilibrium?
- What will the price of membership in an equilibrium be?
- What will the spillover effect on the existing members be, and in what ways are the membership decisions mutually linked?

Our paper introduces an analytic welfarist approach to membership in a defense alliance. References to the real-world NATO alliance are relegated to the footnotes, but this paper does hope to facilitate an analysis of the current burning real-world issues, too. Our focus is on the trade-off between domestically and internationally provided security as public goods. In contrast to the earlier papers on alliances, heterogeneity of potential members is introduced in the model world of the paper in that the risk classification is country-specific. This paper focuses on one source of heterogeneity between members only. Such an approach is not really restrictive. Differences in risk classification may indeed arise from a number of exogenous reasons such as the location of the country, the size of the population, or the defense attitude of the citizens arising from historical development, to mention a few of the most relevant reasons.

In the model world of the current paper, it is assumed that alliance membership is costly. Membership is conditional on the sufficient compatibility of the defense materiel between the members. The member countries must use resources to build sufficient defense infrastructures and military bases, there must be participation in joint training and maneuvers of defense forces, and resources need to be allocated to crisis management programs. These represent the price of membership. An attack against any member by an enemy is not explicitly modeled. In such a scenario, the capacity of each member should, in principle, be available to defend any other member under attack. However, the participation and its scale necessitate a political decision that requires a cost–benefit analysis and may therefore be slow. Thus, it may not be clear what the security guarantees (say, Article 5) actually mean. Apart from that, the commitment may in some contingency be extremely costly. Consider a case where the commitment leads to escalation and potentially to a third world war and the use of nuclear arms. For this reason, it is also reasonable to consider a variant to the basic model allowing for expectations of commitment uncertainty.

The architecture of the model world of our paper will build on the classic approach of Olson and Zeckhauser (1966), but will add more structure. The member countries are heterogeneous in their safety classes. It will also be suggested that planned membership in an alliance can launch preemptive maneuvers or counteractions by the enemy. There are many relevant real-world examples. In our model, the provision of collective security will be analyzed in terms of public-good provision by an alliance with heterogeneous members. A benefit/ cost ratio of membership is derived under a free-riding incentive. There is some novelty in the analysis with respect to the option value. All countries have sovereignty in their decisions on their defense budgets. The idea of a safety class in our paper is innovative from another perspective. Analyzing preemptive maneuvers or retaliatory actions of a potential enemy and the cost of commitment (analogous to Article 5) can be undertaken in a straightforward way in terms of their effect on the safety classification of a member. The idea of the determination of the equilibrium size of the defense coalition is new. With the exception of the paper by Macho-Stadler and Xue (2007), the existing literature does not help in understanding the dynamics of the alliance formation. Moreover, no other paper has analyzed the determination of the equilibrium cost of membership. This task is somewhat challenging when the members are heterogeneous in their safety classes. Consequently, they value the collective good differently. This raises a tricky issue: How is the decision process structured within an alliance when explicit majority decision-making is ruled out? Our paper suggests an innovative procedure with implicit voting, to be analyzed in terms of the median-voter theorem.

Results

The main results are as follows. A sufficient condition for a single low-risk potential member to abstain from participation and a necessary condition for the participation of a high-risk potential member are stated. The optimal tax rate is shown to be declining in the safety classification of a member country. A potentially hazardous effect of the reduced risk from membership on the national defense investment is shown to follow. It is shown that membership can result in a complete crowding-out of the domestic defense capacity. The implications for the option value of membership are stated and extended to the case of imperfect credibility of the commitment and the cost of participation. The solution to the alliance equilibrium is found by fixed-point iteration. The driving force is the dispersion of the security classes. Expectations of the commitment concerning co-members can result in multiple equilibria.

2.4. Offset Contracts as an Insurance Device in Building the National Defence

Defence and Peace Economics, published online 2017, June 02,
doi.org/10.1080/10242694.2017.1335366, published by Taylor and Francis,
co-author: Juha-Matti Lehtonen.

Background

International trade in defence materiel is large. Most countries do not produce all their defence materiel by themselves. Instead, they meet some of their needs by engaging in trade in such materiel with other countries. For example, defence is among Europe's main sectors of industry, fuelling innovation and growth of the wider EU economy. The European Commission has stated that, with a turnover of 96 billion euro in 2012 alone, it is a major industrial sector, generating innovations and centred on high-end engineering and technologies.

The production of defence materiel is characterised by high start-up costs and substantial research and development (R&D) investments. Such regularities point to the exchange as taking place in conditions that may markedly deviate from perfectly competitive markets and as subject to bargaining that generates economic rents. Taylor (2012) points to high transactions costs, incomplete and asymmetric information, and bounded rationality as characteristic of this exchange setting. High fixed costs in production may lead to increasing returns, thereby creating incentives to augment the producer's domestic market with export sales. Often, especially in the case of the aerospace industry, the contracts are of extensive scale, and the materiel represents public goods and is tax-financed by the purchasing government. The products in the markets are imperfect substitutes, and the buyer has to match them with the qualities it is hoping to acquire. These products are typically highly complex and consist of thousands of parts.

'Offset' refers to any type of non-monetary compensation that a procuring government requires an exporting firm to provide as a condition of the sale, and it generally commits the exporting firm to spend a certain percentage of the value of the sale in the procuring country. An offset agreement is a contract between a purchasing government and a foreign supplier. The latter is encouraged or even required to provide additional benefits for the purchasing government's economy, beyond the base transaction. The term 'offset', or sometimes 'industrial participation', is used in connection with military items procured by governments: one factor in this is that, since Article IV.6 of the

World Trade Organization (W.T.O.) Agreement on Government Procurement forbids the use of offsets in general while exempting armaments, 'offset' may be deemed exclusive to defence purchases.

Offsets are commonly divided between direct and indirect, where a direct offset is connected to the item purchased and an indirect offset is not, and between military and non-military (i.e. civilian) offsets. The compensation requirement may take various forms; the U.S. applies the following categories for offset transactions: co-production, technology transfer, subcontracting, credit assistance, training, licensed production, investment, purchases, and other (B.I.S., 2016). Moreover, governments that demand offsets may differ in the amount of offset required and in the multipliers employed in calculation of the offset value of a specific transaction (e.g. B.I.S., 2016).

Offsets are extensively used in trading in defence material. According to Ungaro (2013), offsets between 2005 and 2016 were projected cumulatively to amount to \$500 billion internationally. The view that emerges from the existing literature is that offsets represent marketing devices as nonstandard contracting in international procurement amidst concentrated market structures and are particularly valuable in generating efficiency gains though they represent deviations from free trade. This is even though the European defence procurement directive (2009/81) and U.S. offset policy, echoing the W.T.O. view, are against offsets. Yet in 1993–2008, 48 U.S. firms signed, in all, 677 offset agreements, worth \$68.93 billion. In 2008, 14 companies entered into offset agreements, with 52 contracts, in support of \$6.09 billion in export sales. For the last 15 years, the compensation ratio for U.S. firms that signed offset agreements is 70.96 per cent.

In a study commissioned by the European Defence Agency (E.D.A.), Eriksson et al. (2007) estimated that there is a 40/60 split between direct and indirect offsets in E.D.A. participating member states (pMS) but were unable to estimate the offset transactions' value in relation to contract value. In the U.S.A., the 20th offset report to Congress (B.I.S., 2016) cited a \$171 billion contract value covering offset clauses in 1993–2014, while the offset transaction value in the same period was \$71 billion. As direct offsets accounted for 39,4 per cent of the actual value of the reported offset transactions in 1993–2014 (B.I.S., 2016), one may conclude that the actual value of direct-offset transactions came to 16 per cent of the contract value during that time for U.S. military exports with offsets.

In light of the fact that the international defence trade is very large and that offset contracts are very commonplace in connection with large deliveries, the previous analytic literature on offsets is surprisingly limited. Many fundamental

economic questions surrounding offsets have eluded analytic decision-theoretic and bargaining-theoretic research.

Research questions

The following issues are raised in the current paper:

- Why are offset requirements overwhelmingly dominant in contracts for the delivery of defence materiel, and why do they survive?
- How large is the optimal offset claim to be imposed on its trade by an acquiring country?
- What is the incidence of offsets, given that there can be no ‘free lunch’ in creating insurance?
- How is the price of the delivery contract determined in light of the acquiring country’s demands for an offset?
- How does the offset requirement interact with the scale of the delivery contract?
- What effect does the delivery contract being subject to the offset have on the acquiring country’s national security?

The approach in the current paper

In this paper, we analyse the economic benefits of a direct-offset transaction. A market for insurance against an adverse future contingency does not exist.¹¹ The paper introduces an alternative – and a new – view of the economics of offset requirements imposed by a purchasing country, considering them from the angle of their impact on national security. Australia’s policy of insisting that all industrial activities feeding into Australian Defence Force’s operational readiness have to be domestically provided serves as an example. Moreover, the insurance argument appears to apply to countries in the group of major defence equipment importers in EU of Eriksson et al. (2007) with, say Finland as example, when the risk classification of the country necessitates the ability to activate the defence force with no delay.

The way a country designs the content of required offsets impacts significantly the insurance dimension of contractual requirements. For example, when Finland bought its 62 F/A-18 Hornet planes from the US, it demanded that

¹¹ Large exporting countries (such as the United States and France) do not need offsets, since they strive for self-sufficiency and complete independence. For medium-sized countries with sizeable exports (e.g. Italy and the Netherlands), offsets can be desirable for strengthening the country’s industrial base. In countries that are members of an alliance (such as Denmark or Norway), offsets may lead to the possibility of delivering components, thereby strengthening the interdependence within the alliance.

they are assembled in the acquiring country in order to develop the local skills of services and to keep their flying ability as high as possible. The focus on such an offset requirement was unrelated to the imbalance of trade associated with the acquisition.

According to the above-mentioned directive (2009/81/EC), any offsets within the E.U. must be based on national security, because exemptions from that directive may be made only under Article 346 T.F.E.U. However, the legal concept of national security is not defined clearly in Article 346; it leaves open how offset practices may be related to national security. Nations differ in the objectives they pursue through offsets. Erikson et al. (2006) found that medium-sized countries that primarily export are interested in developing the national-defence technological and industrial base (D.T.I.B.) through mainly indirect offsets in technology transfer and defence exports while mainly importing countries opt for direct offsets. The latter can enhance national security by sustaining national D.T.I.B. capability for equipment maintenance, thereby ensuring equipment availability. One concrete example is that complex defence equipment requires significant training, maintenance, and servicing after acquisition if it is to be able to operate properly. In his case study of the Finnish F-18 deal, Korhonen (2011) explains how direct offset for such operations as assembly and testing aids with maintenance throughout the service life. He concludes that it is especially beneficial in terms of knowledge and skill development if the assembly and maintenance are performed by the same party. Offsets represent the key device for such aims.

In fact, the mechanisms by which offsets enhance the national security are both direct and indirect. The possibility of assembling the aircraft domestically provides the valuable capability of servicing those fighters domestically too. It is widely recognised that high-tech, sophisticated modern defence instruments require periodic servicing and that, hence, many of them are incapable of operating at any given time.¹² An extreme example is the B-2 Bomber, which a Government Accountability Office report (G.A.O., 1997) described as requiring 124 maintenance hours per flight hour, with an ultimate goal at the time of reducing this figure to 50 per flight hour. Clearly, therefore, the risk of not having sufficient defence equipment functional and operative at short notice is high. The necessary servicing involves installing spare parts etc. and having competent personnel on hand, the required tools and testing devices, and updated programs available to facilitate maintenance and repairs. The risk of not having the necessary servicing available when needed from the delivering country is non-trivial.

¹² It was reported in a *Der Spiegel* article of 20 December 2017 that, for example, only eight of the 109 Eurofighters in the German army's equipment base are available for flying, seven of the 67 transport helicopters and five of the 33 NH90 helicopters are in operational condition, and 21 of the 56 transport aeroplanes are in sufficiently good condition for operation. Of course, such cases are not limited to the German army.

However, there is more than a direct impact of offsets on the national security. They also enhance the industrial strength of the acquiring country. This, in turn, has a further spillover, i.e. indirect effect on the national security, since the technology transfer strengthens the operational capability of the economy. Such a vision is analysed in the economic model world presented below, suggesting that the offsets do not represent a free lunch.

In the model world of the paper, the acquiring country firstly decides on its offset requirement. After this, it negotiates with the delivering country on the price of the delivery. Finally, the acquiring country decides on how many units of the defence materiel it is going to buy.

Results

A dynamic multi-stage decision-theoretic approach is introduced to establish the optimal offset and its incidence, the contract price arising from bargaining, and the scale of the acquisition. A new rationale is suggested for offsets in terms of their role as an insurance device. Results are derived for the pricing of delivery contracts subject to offset claims and their national security implications. It is shown that the national security is strictly convex in the offset transaction. As to the incidence of the offset, the offset claim is shown to be capitalised in the delivery price. The bargaining price is shown to depend on the value of the product to be delivered for the national security, the relative negotiation power of the contracting partners and the social cost of public funds. The analysis highlights the expectation effects of offsets on the bargaining price and the scale of delivery. The results aid in explaining why offsets are widely used in procurement contracts for defence materiel. As they contribute to the national security, they should be allowed to survive and not be denied under competition laws.

2.5. Joint Procurements in Building National Defence: Why Are There So Few?

Hecer, Discussion Papers No. 427, March 2018, *Defence and Peace Economics*, <https://doi.org/10.1080/10242694.2018.1471320>, published by Taylor and Francis, co-author: Juha-Matti Lehtonen.

Background

The economic benefits of joint acquisitions of existing defense materiel arise from increased bargaining power relative to the contractor and from reduced (average) costs arising from economies of scale in production. There is, however, a puzzle: why are such procurements so few?

Recently, pressures have intensified among the member states of the European Union to create multinational programmes in terms of cooperative defence procurements. Such a view was forcefully advanced by the President of the European Commission, Jean-Claude Juncker in his speech at the Defense and Security Conference, *In defense of Europe*, Prague, June 9, 2017, stating: “*There are 178 different weapon systems in the EU, compared to 30 in the U.S. We allow ourselves the luxury of having 17 different types of combat tanks while the United States is able to manage perfectly well with just one model. Absurdly, there are more helicopter types than there are governments to buy them! We must do better.*”

The defense materiel has become more and more sophisticated and technically advanced. As a result, its unit costs are constantly increasing. In 2014, the defense budgets of the European Defence Agency (EDA) members totaled 195 billion Euros, of which defense investments amounted to 34.7 billion Euros¹³. The speech by Juncker points out that in addition to better facilitating the control of defense expenditures, qualitative improvements can be obtained by reducing the heterogeneity of the materiel within European countries. Indeed, as it is well-understood, Europe’s defense expenditures do not match their efficiency with the comparable US expenditures, with the European Commission estimating that the EU would not even be half as efficient as the USA.

Over the years, it has been suggested that the cost savings of collaboration in the development of new defense materiel may be significant. A recent NATO report on international cooperation calculates 40 percent savings for the Alliance in an aircraft acquisition example comparing a sole developer and consortium scenario, when considering a 95 percent learning curve and transaction costs. However, while this example is purely theoretical, the report states that “international cooperation is characterized by a striking lack of empirical data on cost savings and operational gain” and “the costing data are usually either classified, too complex to evaluate, or the before-and-after costs are not comparable”. About the only public calculations available with savings figures are the Nordefco webpages, which estimate 100 M€ cost savings in common development, purchasing and maintenance of defense materiel during a fifteen-year period.

¹³ According to the statistics reported by the EDA, the UK (10.3 billion euro) and France (9.7 billion euros) were the dominating countries in European defense investments (including R&D expenditures) in 2014. Germany was the third (4.7 billion euro). The 35 per cent benchmark of the EDA in European cooperation was met only by Spain (46 per cent), Italy (40 per cent) and Belgium (35 per cent) calculated over a 10-year period. Of course, the European average is held up by the UK, France and Germany which carry out most of the defense investments.

Ten years ago in November 2007, the Ministerial Steering Board of the EDA approved four collective benchmarks for investment: (i) Equipment procurement (including R&D/R&T): 20% of total defense spending, (ii) European collaborative equipment procurement: 35% of total equipment spending, (iii) Defense Research & Technology: 2% of total defense spending, and (iv) European collaborative Defense R&T: 20% of total defense R&T spending [8]. Faced with austerity and decreasing military budgets in the aftermath of the 2008 financial crisis, in 2012 NATO launched the Smart Defence initiative for developing, acquiring, operating and maintaining military capabilities in a cooperative manner for cost savings and efficiency. Corresponding efforts by the EDA are called pooling and sharing where pooling refers to having capabilities on a collective basis while sharing means that some countries relinquish some capabilities with the assumption or guarantees that other countries will make them available when necessary.

Collaboration in defense equipment purchasing is not a novel idea. In 2008 there had been 59 collaborative acquisition projects in Europe since the early 50s. Two of the main challenges of collaborative procurement are the harmonization of operational requirements between the participating States, and the agreement on common timescales for the program. In addition, European defense collaboration has been inefficient and inflexible due to the *juste retour* (fair return) principle, where the industry of each participating nation should get a work share that corresponds to the financial contribution of its own government. Collaborative defense procurement programs often incur long delays, both before the actual start of the program and during the development process, thereby providing the required capability much later than expected. The conventional view is that more partner nations make collaboration more complex and inefficient, although they cannot confirm this hypothesis with their admittedly limited number of cases.

Collaboration in armament production has been attempted and has taken place between arms producing countries especially in Europe – though countries protect their domestic production with *juste retour*. Regarding the collaborative equipment procurement benchmark, however, the efforts have not been realized up to the stated targets as the share of European collaborative equipment procurement between 2005 and 2014 was on average 17 % (EDA, 2107).

In the current article, cooperative purchasing is used to refer to two or more countries purchasing existing defense equipment, i.e. military off-the-shelf equipment, in contrast to collaborative purchasing where countries jointly develop and manufacture the equipment that they purchase. As there is no product development, purchasing cooperation holds fewer risks and has a smaller economical minimum unit size, thereby making such cooperation more feasible between smaller nations than collaborative development. In addition to the potential economic gains in purchasing, such as increased negoti-

ation power and sharing of evaluation costs and information, common equipment may facilitate other cooperation benefits in maintenance and in operation phases, such as in training and in maintenance. In an estimation of the potential for cooperative purchasing between the Nordic countries, the same obstacles of matching time-scales¹⁴ as well as similar enough requirements due to independent, national defense planning processes and differences in military tasks were found. Decisions on how to co-operate and with whom should be rooted in a rigorous cost and benefit analysis, along with a thorough public discussion of their industrial and political impact [31]. However, these impacts are not easily quantifiable even if all the relevant data were unclassified.

Cooperative purchasing

Cooperative actions been extensively studied both in private and public sectors but articles dealing especially with cooperation in purchasing are still quite rare [28]. Cooperative purchasing is defined as the cooperation between two or more organizations in a purchasing group in one or more steps of the purchasing process by sharing and/or bundling their purchasing volumes, information, and/or resources. Through co-operative agreements, firms can take advantage of economies of scale in one or more of their production processes while remaining separate entities and cooperation benefits such professionalism and information sharing can be viewed as resulting from scale economies. A number of factors that facilitate more intense purchasing cooperation including a small number of participants, geographical proximity, and similarity in purchasing requirements [4]. Similarity in size also helps because when one big organization dominates, other participants tend to simply use its contracts. It is suggested that success factors for cooperative purchasing groups that include no enforced participation; all members contributing with knowledge and the fair allocation of savings. The organizational form of purchasing cooperation may be determined by the degree of influence held by all members and the number of different purchasing activities involved. In case of a low number of activities they identify a project group organization when all members have influence and a piggy-backing group when a large purchaser lets the smaller one(s) without much influence use its prices and contract. The type of defense equipment purchasing cooperation in this article involves a low number of activities because a high number of activities would have a more intensive form and political implications.

In recent years, there have been a few cooperative defense procurement initiatives in Europe. Table 1 (to be found in the paper below) contains a summary of such initiatives as well as their current status based on articles in Jane's De-

¹⁴ Defense equipment has long life cycle and renewal times and do not easily fall into same time-window. As an example of the timescales for decisions on fighter aircraft in the Nordic countries: Sweden has a fleet of JAS Gripen, Norway selected the F-35 in 2008, Denmark in 2016, while Finland plans to select an F-18 replacement in 2021.

fense Weekly. However, an overall picture emerges with just a few (11) cooperative purchasing initiatives regarding major defense equipment. Out of those initiatives, three involving the Czech Republic were cancelled while the other eight are either completed or at least not cancelled. Some initiatives have complicated histories with multiple twists and turns, such as the Nordic helicopter purchase with Denmark quitting the consortium, and the tanker aircraft where most of the initial initiative countries have pulled out, but now Germany intends to join again with an expected purchase decision by 2019 and the Rheinmetall MAN trucks initiative where reported issues included delays after Norway pulled out of the collaborative Archer project with Sweden as well as legal concerns with the deal. The Smart Bombs provided by the U.S.A. were enabled by a recent change in the American legal interpretation that until now excluded Foreign Military Sales to a consortium.

In terms of consortia, there are three large, multilateral projects involving NATO and EDA countries of which the Global Hawk is a Smart Defense initiative (Alliance Ground Surveillance) and the A330 Air Tanker is an EDA Pooling and Sharing initiative (Air-to-Air Refueling). The remaining initiatives in Table 1 include mostly just two, or in two cases, four small countries that are either Nordic or Visegard countries working together.

It would be natural to assume that given the small defense budgets of, say the Baltic states, cooperative procurements would be regularly adopted between these countries. Similarly, it would be expected that cooperative procurements would be typical among the Nordic countries. As Table 1 shows, this is not the case, and in fact the situation is quite to the contrary.

Research tasks

When it comes to considering the collaborative acquisition of materiel, i.e. collaborative R&D and production, the share of collaboration in the overall investment may be low because many countries want to protect their domestic industries and producers of the defense materials. There are also problems in the commitment to joint efforts within, say, NATO. That there are so few cooperative purchases of materiel is harder to explain. It has been noticed that in a large number of cases, the advantage of cooperative purchasing outweighs the costs of cooperation and other disadvantages such as anti-trust (legal) issues and disclosure of sensitive information. However, small and intensive purchasing groups do not flourish and such groups often prematurely end their cooperation. The economic benefits of a cooperative procurement as a joint venture arise from increased bargaining power relative to the contractor, and from reduced costs arising from economies of scale in production. They can be expected to provide economic incentives to participate in a procurement alliance. There are potentially other benefits like in collaboration, whose objectives may be grouped into three main categories: economic, operational and political ones.

There is thus a puzzle. Why are cooperative procurements of defense materiel so rare? The current paper therefore asks three questions:

- Under what conditions do the incentives for creating procurement joint ventures arise?
- Why do the cooperative procurement efforts so seldom take place?
- When are cooperative procurement coalitions stable?

To address these issues, the paper introduces a bargaining model with forward-looking expectations concerning the scale of delivery contracts. The previous analytic literature on collective procurement is rather limited and no such a theory has been suggested in terms of an analytic approach. To develop such a theory, one has to introduce the trade-off between the cost savings and the impact of the procurement on national security in a case where the option of cooperative procurement is available but where the countries are heterogeneous with regard to their preferences.¹⁵

In the development of the analytic model of the current paper, the following mechanisms are introduced. The defense structures in organizing national defense are typically nation-specific. Such a heterogeneity may result from the need for differentiated products and may require side payments (“bribes”) between the members in the joint venture to make it sustainable. This appears a harsh requirement. The potential opportunism in collective procurement may be controlled and commitment sustained if the interaction between the coalition and the producer is repeated and if the partners adopt appropriate punishment strategies for sustaining the partnership, such as abstaining from future commitments in a credible manner. The Folk Theorem suggest then that the set of feasible potential contracts is rather large but that some punishment strategies are needed to secure the survival of the partnership. Such a punishment may include the exclusion of the deviating partner member from the economic benefits from the subsequent cooperative procurements.

There is a further subtle issue. At the negotiation table, the participants apparently understand that the unit price to be settled will have an impact on the scale of the acquisition. The paper plans to address this issue. It will show that

¹⁵ It has been reported that in the case of NH90 helicopters, Finland was searching for a transportation helicopter, Denmark for a rescue helicopter, Norway for a helicopter for catching submarines, and Sweden wanted a helicopter with all these properties conditional that the helicopter would have Saab systems [19]. As an amusing anecdote was the suggestion by one of the countries that the helicopter should have an option for toilets while another country demanded that the option should include a toilet both for male and female soldiers [20]. The final offer by the producer included the option for a toilet but was so expensive that the toilet option was disregarded on short notice. There was more to it. Of the 18 NH90 TTH helicopters ordered by Sweden, 13 were of high cabin versions facilitating surgery operations to be carried out by taller male doctors.

the price sensitivity of the scale of acquisition is favorable for the buying partnership as it tends to depress the bargaining price.

Results

Several explanations are proposed as to why it is, however, hard to align the incentives of the buyers. First, the preferences concerning the properties of the products are country-specific with divergent implications for national security. Second, a country with a low valuation of the product has more bargaining power than a country with a high valuation and may expect a side payment from the partner of the procurement, while the latter may not have sufficient incentives to pay. Third, the gains from cooperative procurement in terms of economies of scale for the producer may, after all, not be sufficient to compensate for the conflicting preferences. Fourth, while the future unpredictability of technologies or the future risks of deteriorating national security might support longer-term joint procurements, short-term opportunism tends to prevent long-term commitments. The paper shows, however, that long-term commitment may be even more difficult to achieve not least because of the uncertainties attached to the future development of the defense needs in strengthening national security and the unpredictability of the advancement of new defense technologies

2.6. Cyber Technology and Arms Race

HECER discussion paper N:o 424, February 2018.

Background

In June and July of 2010, the world learned about Stuxnet, a malicious computer worm believed to be jointly created by American and Israeli cyber weapon specialists. Experts have been convinced that Stuxnet was meant to sabotage the uranium enrichment facility at Natanz in Iran and its centrifuge operational capacity, but the damage spread to other units, too. It is believed that most of the infected computers worldwide by Stuxnet have been in Iran. Judging from such a cyber operation, Israel apparently preferred to mount a cyber attack rather than a military strike on the nuclear facilities of Iran. There is little downside to such an attack because it would be virtually impossible to prove who did it. Though the attack against Iran was a success, the same is not true of the corresponding attempts to cause damage to the nuclear program of North Korea. It is conceivable that such strikes have been planned and even attempted. With computerised instruments like Stuxnet, the world has entered into a new age, the era of cyber war.

Cyber technology represents digital military capability with the purpose of causing damage to the military strength of a potential enemy. War using conventional weapons may be preceded by or combined with a strike using cyber technology. Cyber issues are rapidly growing in importance to defence alliances. At the Wales Summit in 2014, allied heads of state and government affirmed that cyber defence is part of NATO's core task of collective defence. Ambassador Sorin Ducaru, NATO's assistant secretary general for emerging security challenges, gave a statement about NATO's efforts to improve its cyber defences against emerging threats. The message is that by treating cyberspace as an operational domain, NATO aims to better protect its missions and operations. It will assist in the management of resources, skills, and capabilities, and will also ensure that cyber defence is better reflected in military planning, exercises, training, and how NATO responds to crises. One of the questions is whether Article 5 would be triggered in the case of a cyber attack on a member country. Until recently, the political impact of cyberspace was thought to be a matter of low politics—background conditions and routine processes and decisions. Now, however, experts have begun to recognise its effect on high politics—national security, core institutions, and critical decision processes.

The digital world has changed warfare not only in terms of the destructive power of the weapons and direct damage to the efficient use of the technology-dependent weapons of the opponent but also indirectly causing paralysing effects on the society at large. By its logic, a cyber attack represents a pre-emptive offensive, typically a remote action employing digital technologies to damage the social and/or military capabilities of an enemy. As cyber capability represents an instrument prior to a war with conventional weapons, modern warfare may consequently be viewed as a multi-stage game. A war with conventional weapons tends to be preceded by a cyber war. A static one-stage approach, therefore, does not appear appropriate. The potential of cyber capability appears unlimited. The following mechanisms may be relevant: (i) both the cyber and the conventional military capabilities of the defender can be disturbed if its cyber capability suffers from the attack, (ii) a cyber attack need not result in civilian casualties, and (iii) the attacking country cannot easily be identified by the target country. Therefore, it is not trivial to initiate a counterattack. For these reasons, the threshold for a cyber attack may be low. A good question then is: how strong is the incentive to exploit the first-mover advantage from innovative success?

Though our cyber war approach has a similar flavour with the economic literature on sabotage, there are differences. While the sabotage papers consider one-time decisions, our approach leads to sequential decision-making with a first-mover advantage in terms of a pre-emptive strike. The model allows for asymmetries between the hostile countries to produce cyber capabilities. The probability of winning a war is strictly convex in its size. This is the remarkable property of the model. Moreover, while the papers on sabotage state that

expectations of being sabotaged have a discouraging effect (causing the participants to reduce their effort), this is not the case in the current model.

Research questions

Access to a cyber attack raises a number of new questions:

- How worthwhile is it to invest in conventional weapons if countries can resort to cyber instruments?
- Does the answer depend on the differences in cyber capability?
- What are the implications for the arms race and the probability of warfare?
- Is it always the case that a cyber war is followed by a war with conventional weapons?
- Does the threshold to a cyber war differ from that of a conventional war?
- How much is it optimal to invest in the cyber capability if the expected success differs between the conflicting parties?

These are the issues to be analysed in the current paper and some of the answers turn out to be unexpected. The roadmap of the model world of the paper is as follows. The cost of war is first introduced in the standard model of contests. Then, an investment in cyber technology is introduced into this model in terms of the probability of being victorious in warfare. The investment in cyber capability is considered risky in terms of the outcome of the development effort. The outcome is private information for each country. The country that turns out to be more successful finds that it has the option of initiating a cyber attack against the enemy, but without knowing whether the enemy has been successful in its rival development effort, too. After the cyber war stage, the countries enter warfare with conventional weapons. It is a fundamental notion in the model world of this paper that the war cannot be won by a cyber attack only: conventional weapons are needed to capture the prize.

Results

The results of the paper can be summarised as follows. The cost of war turns out to be crucial for the results in that the equilibrium analysis in the war game is conditional on the cost of war relative to the payoff to being victorious. First, in the war game two types of Nash equilibria subject to warfare are possible depending on the cost of war relative to the payoff from victory. Both are subject of warfare. Under “small” cost of war, armament in conventional weapons is large; under “large” cost of war, armament is smaller. Second, if

countries expect to have access to equally effective cyber capabilities, their cyber investments are neutral in respect to the optimal investment in conventional weapons but only when the cost of war is small. Such a symmetric case is not necessarily typical if countries have access to different technological skills and competence to start with. The third result is therefore concerned with an asymmetric case. It is shown that hostile countries choose to invest an equal amount of resources in their militaries, even when their cyber capabilities differ, but under low perceived cost of war, they invest less than in the absence of cyber war technology. Surprisingly, they invest more when the perceived cost of war is bigger. Moreover, the fourth result is rather dramatic in showing that *cyber technologies can make the world unsafe*. The intuitive reason is that technological advances in cyber capability lower the cost of war in conventional weapons. The fifth result adds to the concerns of the cyber war given that cyber technologies are difficult and costly. Namely, heterogeneity in the success of cyber programs creates the option of a pre-emptive strike. The paper shows that a low success probability of the cyber program encourages exercising the cyber attack option by a successful country to be followed by warfare with conventional weapons. A successful cyber program means a new set of beliefs of the winning probability in the conventional war. The odds have been changed in favour of the attacking country.

3

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