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Article *in* Journal of Innovation Economics & Management · September 2013

DOI: 10.3917/jie.012.0059

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TECHNOLOGY AND THE DEFENSE INDUSTRY: REAL THREATS, BAD HABITS, OR NEW (MARKET) OPPORTUNITIES?

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ABSTRACT

Technology has been playing a central role in defense spending or arms-producing countries since World War II. Although there has been no major threat or conflict since the 1990s, defense R&D absorbs a large share of military expenditures, as well as public R&D. This technology-centric paradigm results from uncertainties surrounding defense matters and the need to avoid strategic surprises. However, one can wonder whether such a paradigm is still adapted to today's defense needs. This is a trend strongly driven by the supply side: defense firms have developed a business model that cannot survive without launching new programs, hence a high level of defense R&D. This explains both an overinvestment in technology, resulting in the development of unaffordable technologies or unsustainable performance targets, and the technology-centric model that defense firms favor in side markets like security.

KEY WORDS

Defense, R&D, technology, security, procurement

JEL

H56, H57, O32

INTRODUCTION

Despite the end of Cold War, armed forces continue to allocate a large share of their investment effort to defense R&D, particularly in arms-producing countries. Emerging powers like China, India and Brazil are also dedicating an increasing share of their defense budgets to R&D while these countries were not use to invest so heavily in this domain.

One may wonder whether such investment results from the need for new capabilities, linked to existing or emerging threats, and whether the outputs of defense R&D match the expectations. Defense R&D has been widely criticized since the 1970s in the economic literature because of its opportunity cost

[1] The author is grateful to Susan Dewavrin, Josselin Droff, Stanislas de Lauriston and Enno Schumacher as well anonymous referees for their fruitful comments. All usual disclaimers apply.

and its relative ineffectiveness compared to civilian R&D (Lichtenberg, 1995). It is therefore quite surprising that this part of defense spending was sheltered or at least preserved from budget cuts after the end of Cold War although there were mainly low-tech conflicts since the beginning of 1990s.

Such a situation reflects a paradigm shift in the twentieth century. The defense industry and armed forces' procurement have been driven by technology since World War II and this industrial model has survived after the collapse of the Soviet Union. Nevertheless one can ask if a technology-driven defense market is still able to deliver capabilities that armed forces require for today's conflicts.

Moreover does this technology-centric approach correspond to today's business model of the defense industry and does it respond to a true need to face potential threats? This focus on technology has characterized the so-called "military-industrial complex" for four decades. However, is this approach still relevant in the post-Cold War era? Or are defense firms mainly trying to preserve their technology-driven industrial model?

This paper aims to address these questions. Part one underlines how the technology-centric paradigm has been dominating defense capabilities since the end of World War II and why it is still dominant in arms-producing countries despite the end of Cold War. Part two looks at the limit reached by such a paradigm when dealing with current conflicts or ongoing programs, even though advanced technology seems to remain a core parameter in current and future defense efforts. This leads to look at the predominance of technology in defense firms' strategy, which explains both the limits reached through a technology-centric approach and the repositioning of these firms on the emerging market of security.

1. <u>THE PERSISTENCE OF A TECHNOLOGY-CENTRIC DEFENSE</u>

While military capacities have always played an important role in defense matters, a new paradigm emerged in the 1940s centered on technological issues. Such a paradigm was steadily reinforced by the Cold War and it survived after 1990, since a technology-centric defense is still considered the best approach to solve security challenges – at least for the largest military spenders.

1.1 Technology disruption as the driver of military capabilities

Since the 1940s, armed forces have fielded advanced technology through an aggressive pursuit of R&D and the development of a high-technology defense industrial base of unprecedented scale. Technological superiority is considered to be a key element to achieve defense effectiveness, and R&D plays a major role in accessing relevant advanced technologies. This explains why the United States and Western European countries have been pouring a large share of their R&D expenditures into applications for defense since World War II.

Technology played a minor role before the middle of the twentieth century, but World War I and even more World War II marked a radical change. This latter demonstrated the potential that scientific and technical progress can provide to armed forces, thus legitimizing large R&D budgets in most industrial countries. This was a major change, which has given birth to what Freeman and Soete (1997) called "Big Science." For instance R&D spending in the United States represented only 0.8% of federal budget in 1940, but more than 10% by 1960 – and defense R&D received most of these additional resources.

Such a dedication proceeded from major successes in defense R&D like the "Manhattan" project. As Väyrynen (1983, p. 63) states, "the invention of the atomic bomb modified entirely the importance of technology towards national military policies." The greatest advocate of defense R&D was unquestionably Vannevar Bush, who supervised technological projects for the Pentagon during World War II. In *Science, The Endless Frontier*, he popularized the idea that government-funded R&D produces large technological spin-offs. His book revealed how much the war effort generated technological opportunities and argued that it is fruitful to maintain it in peacetime. Vannevar Bush created a founding myth, which soon became the justification of government-funded R&D (both military and civilian).

The Cold War reinforced this technology-centric paradigm, as the USSR and the United States were looking for means that would provide strategic superiority at whatever costs. In a seminal paper on industrial policy, Reich (1982, p. 864) states: "Large scale defense and aerospace contracts have provided emerging industries in the United States with a ready market for which they have expanded production and thereby gained valuable experience, know-how and scale economies. The Pentagon's willingness to pay a high premium for quality and reliability, moreover, has helped emerging industries bear the costs of refining and 'debugging' their products."

Indeed armed forces have been able to spend large amounts of R&D to sustain disruptive technology as well as achieve incremental innovations, because a "small edge in performance can mean survival" (Alic *et al.*, 1992, p. 114). This paradigm is not only a result of the quest for technological superiority, but also from the need to avoid strategic surprises that can result from scientific and technological path-breaking innovations. As Gansler (1989, p. 217-218) puts it, "we have what refer to as the technological imperative: because we can have it, we must have it (...) Technological opportunities resulting in incremental changes are rapidly accepted and enthusiastically pushed forward–perhaps too unquestioningly."

Such a quest for technological superiority and innovation makes sense when armed forces are trying to preserve and reinforce their strategic superiority. However, by nature, scientific and technological opportunities are unpredictable. In order to face such uncertainty, armed forces try to avoid strategic surprises by anticipating any possible technological disruption.

Saunders et al. (1995) explain that it is imperative to prevent "technological surprises," which threaten or jeopardize national security. Services are extremely risk-averse, in the sense that the cost of failure to find the best technology (technically speaking, of course) can appear very high. Research by definition is risky, and to maintain technological superiority armed forces must allocate a significant share of their resources to basic and applied research in areas of high potential technologies. Regardless of whether such investments succeed, failure can actually be one of the desirable features of advanced R&D, because it demonstrates that a given technology cannot be used by an enemy. If there are not some failures, technologies might not be pushed far enough nor all its military uses explored.

By exploring alternative technologies, defense R&D helps maintain technology scouting by continuing "experimenting long after a market would have standardized on one technology" (Cowan and Foray, 1995, p. 865). Defense R&D in new technologies eventually makes these technologies affordable by moving them along learning curves, lowering costs for later civilian adopters. Defense R&D can then be considered as a complementary action vis-à-vis commercial firms, as it can provide what market mechanisms fail to supply. When the military supports more than one technology in the development phase, it increases the choice of civilian users, especially in the case of new, complex and/or expensive technologies.

Once driven by the East-West arms race, technological superiority continues to be the core of defense procurement. Although Western countries no longer face the threat posed by a global peer competitor like the former Soviet Union, they still live in a very dangerous world. Western armed forces feel that strategic surprises can be avoided by mastering innovation and disruptive technology. This explains why defense R&D remains a key dimension of defense spending.

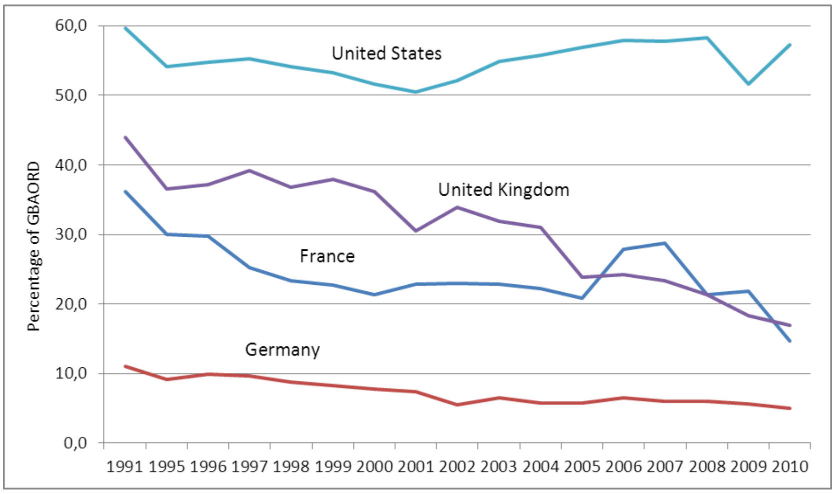
1.2 Still a large effort of R&D in defense

Trends in military spending show that a defense technology race remains at the heart of defense procurement in the Western world. Despite the end of Cold War, defense R&D absorbs a large share of defense spending although no country is able to challenge the United States or NATO countries in the field of defense technology, at least in the medium term.

Conflicts since the 1990s can be identified as low-tech wars. Gulf Wars I and II demonstrated this by proving that the most dangerous enemies or troublemakers did not possess high-tech capabilities; and that there is a major technological gap between NATO countries and most other countries. There is indeed a technological barrier to reach the most advanced military capabilities (Middleton et al., 2006), which naturally protect NATO countries for several years from any technologically-sound military competitor – including China, India and Russia.

Nevertheless, defense R&D remains a central component of scientific and technology investment in large arms-producing countries, as illustrated in the graph below. Through all transformations of 1990s and 2000s, armed forces have preserved their ability to invest in R&D. One can note that the Pentagon was very careful to "sanctuarize" such budget in the 1990s, when "peace dividends" led to a one-third reduction of its budget. Even though defense R&D was less protected in other large arms-producing countries, they remained larger than expected, especially when the economic impacts of defense R&D were highly challenged (Lichtenberg, 1995; Serfati, 1995).

Graph 1 – Defense R&D as percentage of total GBAORD



GBAORD: Government Budget Appropriations or Outlays for R&D
Source: OECD, *Main Science and Technology Indicators*, various issues.

Therefore defense R&D has kept a key role in the national innovation systems of arms-producing countries. One may wonder why armed forces have not changed their strategy, especially since their budgets are under pressure (except for the United States since 2001) and recent wars have not required advanced capabilities. In fact, the post-Cold War era demonstrates that the technology-centric paradigm was not only related to this specific period but translates a radical change in the way armed forces conceive military matters. This is particularly relevant in the United States, where technology has become and will remain the essential dimension to win wars.

Even though technology is neither the unique answer nor effective by its own right, it is perceived as crucial to analyze threats and to maintain military dominance. This is the reason why merely sustaining the technological effort is not considered an option but a necessity to counter unexpected – and sometimes unpredictable – foes. This view also explains why the United States and Europe have kept spending over €65 billion a year in defense R&D over the last decade, according to the European Defense Agency.

Maintaining technological superiority requires an effective technology policy both in terms of operational and budgetary impacts. This is the reason why R&D represents between a quarter to half of equipment spending of large NATO countries, as shown in the table below. Such a policy can appear as expensive, and it can be questioned whether the technology-centric paradigm is still relevant to defense missions.

Table 1 – R&D share in equipment spending

	2005	2006	2007	2008	2009	2010
France	38.1%	37.4%	33.4%	34.4%	35.0%	30.2%
Germany	23.2%	21.9%	25.2%	18.2%	17.3%	20.5%
Spain	8.1%	7.9%	10.5%	11.0%	10.4%	n.a.
Sweden	n.a.	18.7%	18.8%	20.7%	16.0%	9.4%
United Kingdom	35.3%	34.8%	31.4%	29.4%	26.5%	25.5%

EU-26	25.4%	25.0%	22.7%	20.5%	19.0%	20.4%
United States	40.7%	41.1%	36.6%	32.6%	38.3%	36.5%

Source: European Defense Agency, statistical surveys, various years.

The predominance of this technology-centric paradigm can be easily identified through the official publications of large arms-producing countries. For instance, in June 2008, France released a defense review[2] that called for an increased effort of defense R&T and for the launch of technological demonstrators. The subsequent Defense Program Law emphasizes such a trend, with a significant increase of effective spending since 2008.

Similarly, the United Kingdom has preserved its defense R&D effort in spite of budgetary tensions. Although the above graph and table show that R&D expenditures have been decreasing over the last few years, the British ministry of defense still considers technology as a vital dimension of its strategy. This position was reaffirmed in February 2012 when the British government published the policy paper entitled *National Security Through Technology – Technology, Equipment, and Support for UK Defence and Security*. It is noticeable that, in this specific approach, the preservation of defense-related R&T goes through a more global perimeter of activities, because this policy paper explicitly takes into account civilian security.

Beyond the "historical" leaders of defense R&D, emerging (or re-emerging) powers seem to follow the same technology-centric paradigm. Non-western countries such as Russia, India, or China have been increasing their defense R&D since the 1990s, while they have yet to reach a maturity level similar to that of the biggest NATO spenders. Finding reliable statistics about defense R&D spending in these countries proves very difficult and the reliability of data is questionable. Even the Pentagon is very cautious when it estimates China's military spending.[3]

Nevertheless, emerging countries are focusing more and more on advanced technologies for their defense capabilities, and the situation is very similar in Russia, India, Brazil and Turkey. It appears that any country, which has military ambitions and enough resources, is dedicating a large share of its defense budget and economic resources to defense technology.

The predominance of a technology-centric paradigm can be explained – at least partially – by the evolutions of international relations since the end of 1980s, as well as the transformation of threats. In other words, armed forces can perceive technology as a means to anticipate threats (in a technical and operational perspective) and increase their ability to manage more and more heterogeneous configurations.

1.3 Managing uncertainty through technology

Since the 1990s threats have become dramatically more diverse than ever. Most armed forces consider advanced technology as an appropriate and adequate answer to both traditional enemies

[2] *Livre blanc sur la défense et la sécurité nationale*, particularly from p. 269.

[3] See for instance U.S. Department of Defense. 2012, *Military and Security Developments Involving the People's Republic of China 2012*, Washington D.C., Office of the Secretary of Defense, May.

and disruptive ones. Peacetime, or a close equivalent, is a difficult time for a nation's arms buyers, since there is no readily available guide to what should be acquired. Such a difficulty is increased when uncertainty is high about potential threats and risks, as is the case in the post-post-Cold War era. As Donald Rumsfeld (then U.S. Secretary of Defense) put it, "our challenge in this new century is a difficult one: to defend our nation against the unknown, the uncertain, the unseen, and the unexpected" (Rumsfeld, 2002b: 23). This analysis of an uncertain as well as unpredictable world is at the core of the defense policy of major countries, particularly the United States[4], the United Kingdom[5] and France.[6]

Sapolsky (2001) underlines that this is the main reason why the so-called "Revolution in Military Affairs," launched by the Pentagon in the 1990s, appears so jumbled. A true revolution in military affairs is more than building new high-tech weapons; this process is also about new ways of thinking defense and fighting. Armed forces do not only require improved systems but also alternative ones and new doctrines to employ both new and old systems.

Such uncertainty seems even more important because of asymmetric threats and the lack of a clearly identifiable enemy. Defense planners cannot know precisely what kind of risks they have to avoid or fight, so that they must assure that forces can rapidly counter them by increasing their conceptual and organizational adaptability and flexibility. Such an evolution has strong implications at the procurement level, for acquired systems must be reoriented towards new missions, and new needs must be satisfied quickly.

This implies that armed forces allocate a substantial amount to defense R&D for two reasons. First, as potential foes can also have access to much state-of-the-art technology and capabilities, accessible on the open global market, it is necessary to "run faster" than others. Second, potential foes might adopt non-conventional means to overcome the technological superiority of today's military powers. It is therefore necessary to explore a larger scope of technology that could be used for military purposes and evaluate their possible impacts on the military balance.

In fact current armed forces are structured in battle systems prepared to face classical conflicts, where professional units try to acquire the means of tactical and strategic superiority thanks to training and equipment. The East-West rivalry was completely based on such a philosophy, with doctrines aimed at guaranteeing a victory through a major conflagration: the decisive battle. The arms race resulted from the attempt to gain technological and quantitative superiority, but both sides shared a similar vision of war. "Daughter of World War II's confrontations, notes La Maisonneuve (1997, p. 196), the Cold War favored the accumulation of armaments and a race to their modernization. Modern armed forces are those of quantity." Indeed, for at least a century, armament policies have been a quest for strategic balance, characterized sometimes by great oscillations but always corrected quite rapidly. However today's geopolitical situation is rather characterized by an out-of-balance situation.

[4] U.S. Department of Defense. 2012, *Sustaining U.S. Global Leadership: Priorities for the 21st Century Defense*, Washington D.C., Office of the Secretary of Defense, January.

[5] British Defense Secretary: Hammond P. 2012, *Shared Security: Transforming Defence to Face the Future*, Berlin, speech given to the German Council on Foreign Relations, 2 May.

[6] Délégation aux affaires stratégiques. 2012, *Horizons stratégiques*, Paris, French Ministry of Defense, April.

How can armed forces manage their procurement policy when the rules of war are changing, at least partially? Current defense procurement principles become obsolete, but are not replaced by new ones. It is possible to draw a list of asymmetric threats, and many analysts do so. For instance, McKenzie (2001) identifies a typology of six potential asymmetric threats: nuclear, chemical, biological, information operations, operational concepts, and terrorism. However this kind of list is not necessarily useful here. It is more relevant to understand how armed forces can prepare themselves to emerging, unexpected threats rather than targeting only those that have been identified. In a way military powers are still trapped in a "Maginot line" system, relevant during the Cold War but less and less effective today. In fact, "as in judo, notes Saint Germain (2001), [our potential adversaries] are going to challenge us not with the same weapons but in targeting our weaknesses".

NATO countries focus their reply mainly on technological innovations and weapons superiority, notably developing multi-purpose systems. While multipurpose systems are seldom as efficient as single-purpose ones, they may make the most sense because of the great uncertainty about foreseeable threats. Nonetheless single-purpose systems remain relevant when the strategic environment becomes clearer and specific threats are identified. Procurement strategies sould be revisited and modified to integrate these new constraints, leaving more room for new or unconventional programs.

Interpreting the impacts of 9/11 events Donald Rumsfeld used an eloquent image to describe the situation Western armed forces have to face: "It's like dealing with burglars. You can't possibly know who wants to break into your home, or when they might try it–but you do know how they might try it–and that you need good, solid deal bolt on your front door. You know that they might try breaking through a window–and that you need a good alarm system. You know it's better to stop them before they get in–and that you need a police force to patrol the neighborhood and keep the bad guys off the streets." (Rumsfeld, 2002a)

Weapons acquisition takes place today at two levels: non-symmetric and asymmetric. Classical armament remains important in a large field of international relations. Even though no classical threat may rise in foreseeable years and the American dominance appears uncontested, it seems unwise to get rid of major weapon systems since they remain the basis of the military balance between States in the long term. The United States has then developed a preemptive strategy to prevent potential rivals from investing in defense technology by raising entry barriers thanks to their own defense R&D effort… Nevertheless this dimension is not sufficient because of asymmetric threats. It is also necessary to develop a new way of thinking to prevent and anticipate "flaws in the wall." Uncertainty concerning intentions of asymmetric actors and the possible evolution of threats implies a divide of the strategic field in numerous scenarios.

Preparing for the future in an uncertain world requires innovative visions, as well as forces and capabilities that can adapt quickly to new challenges and unexpected circumstances. As Metz and Johnston (2001, p. 15) explain: "While iconoclasts and nonconformists should not rule the military, they should be valued, preserved and heard." However such an evolution does not appear as self-evident. It requires not only a complete revolution in the way military procurement is handled, but also a great awareness on more and more diversified scientific knowledge and technology.

The loop "identified threat/corresponding technology" appears necessary but not sufficient, and armed forces can no longer rely on pure defense technology. More than ever armed forces must prevent military "surprises". The latter were essentially localized in technological fields, but nowadays emerge from various sources… This can lead to an increase rather than a reduction in defense R&D as a means to increase technology scouting and enhance the awareness about possible strategic disruptions.

If such a strategy is necessary, is it enough and truly appropriate? For instance the overemphasis on technology in Western countries could lead to underestimating the many low-tech means and ways by which adversaries could asymmetrically respond to one country's technological supremacy. Such supremacy did not prevent the Netherlands' defeat in Indonesia, France's defeats in Indochina and Algeria, or more recently Russia's difficulties in Chechnya. Even the United States cannot rely solely on its technological superiority, since it does not automatically guarantee victory on the battlefield (as the Vietnam War demonstrated). Actually it is not possible to find a technological silver bullet for each asymmetrical threat. Although technology remains a crucial element in military battles, an alternative approach might be found.

2. DEFENSE FIRMS' STRATEGY IN A STALEMATE?

Today's defense R&D model, set up during the Cold War, appears less and less adapted to deliver defense innovation at a sustainable cost. Not only budgets seem out of control, but one could also question the choices made in terms of R&D targets. This leads to wonder whether defense R&D provides military capabilities or rather helps sustain the business model of the defense industry. This second hypothesis can be validated when analyzing how these firms are repositioning on the security market and how they are molding such a market through a technology-centric paradigm.

2.1 The drifting costs of defense R&D

Even though advanced technologies can support some missions and maintain strategic dominance for arms-producing countries, defense R&D has become increasingly expensive while being less and less able to generate disruptive technologies. Serfati (1995) had already underlined the fact that defense R&D was focusing on incremental innovations, which are by definition much more difficult to achieve and therefore increasingly costly. Almost two decades later, one can note that such an approach has not changed when reading official reports on the management of defense programs. Almost all programs of complex systems are encountering major difficulties concerning either technological developments or budgetary targets.

As the biggest military spender, the United States provides the most relevant experience of the limits in the dominant model of defense R&D. In spite of doubling its global budget from 2000 to 2008, with outlays growing from $386 billion to $736 billion (constant FY 2012), the Pentagon is experiencing technology shortcomings and failures. One can be surprised, since over the same period, the RDT&E line of Department of Defense (DoD) budget increased from $47 to $82 billion. As underlined in the table below, defense technology appears more and more expensive. One can ask if there is a systematic underestimation of the development cost of selected technologies and if the industrial and technological base is unable to deliver expected outcomes.

Table 2 – Changes in DOD's 2011 Portfolio of Major Defense Acquisition Programs

	1 year comparison (2010 to 2011)	5 year comparison (2006 to 2011)	Since first full estimate (baseline to 2011)
Increase in total R&D cost	$14 billion 4 percent	$39 billion 14 percent	$113 billion 54 percent
Increase in total procurement cost	$61 billion 5 percent	$192 billion 19 percent	$321 billion 36 percent
Increase in total acquisition cost	$74 billion 5 percent	$233 billion 17 percent	$447 billion 40 percent
Average delay in delivering initial capabilities	1 month 2 percent	9 months 11 percent	23 months 32 percent

Source: U.S. Government Accountability Office, *Assessments of Selected Weapon Programs*, GAO-12-400SP, Washington D.C., March 2012, page 171.

If the Pentagon provides the most obvious example of such drift, major arms-producing countries are in a quite similar situation. Kirkpatrick (2004) or Pugh (2007) underline that fixed costs represent a larger and larger share of defense programs, and R&D constitutes a key element in these costs. In other words, such programs appear overambitious in terms of technology and performance. One can wonder whether these outcomes result from the management of defense R&D or from inadequate objectives.

Moreover, one can wonder whether defense R&D is truly useful, since economic literature shows that its effectiveness results from both the spending level in a given technology and how this spending is managed. In fact, threshold affects results from the evolution of defense-related technologies. In particular, one cannot expect a linear relationship between R&D spending and its output: below a certain level of investment in a given technology, the output of R&D falls rapidly. Exploring investments in integrative technologies in a dynamic optimization framework, Setter and Tishler (2006, 2007) find that under nonlinear, convex development costs it is not optimal to build military forces using a myopic, short-term approach. It is difficult to transform an armed force within a few years. Consequently, early investment in technological infrastructure is required because entry cost in technology is high and transformation period extends over more than a decade.

If a country's investment in a given technology is too limited, it cannot expect to keep pace with the state of the art, and it is not worth investing in that technology. This explanation can cover part of technology issues, especially for countries with limited budgetary resources. When looking at EDA statistics, it becomes obvious that defense R&D is not optimally used. Nevertheless it seems insufficient to understand the limits or stalemates of current defense R&D.

Reports from public audit organizations in France[7] and the United Kingdom[8] put into relief that armed forces choose immature or unproven technologies that could jeopardize the delivery of capacities, while such specifications are not essential to achieve armed forces' missions. As Rogerson (1990, 1994) demonstrates, there is a systematic bias in the defense procurement in favor of quality even though this choice results in a reduced quantity of systems.

Such a context has nurtured an industrial environment in which firms are encouraged to promote advanced technology rather than look to minimize unit costs (Serfati, 1995; Bellais, 2000). Therefore today's drift in R&D costs reflects, for a large part, the business model which has characterized the defense industry since World War II. The blame should be put on the technology-centric paradigm that defines the essence of such an industry.

2.2 Missed targets or wrong strategy?

One may therefore wonder whether current R&D policies can achieve their goals or whether they should be reviewed, especially to manage tensions between capabilities required immediately and the development of advanced systems that can take years or even decades. When U.S. armed forces were deployed to Iraq and Afghanistan, the Pentagon was accused of neglecting the protection of ground forces while allocating fantastic budgets to programs like the F-22 fighter aircraft whose relevance to these operations was inexistent.

Two dimensions can be criticized about the way defense programs are defined: armed forces focus on incremental innovations that appear more and more costly; and both armed forces and the industry tend to favor technology-intensive solutions, which is not always the best way of solving issues.

First, armed forces seem to have too many weapon systems they do not necessarily need and too short of those they do need. "But in spite of these shortages, as underlined by Rumsfeld (2002b: 28), the department postponed the needed investments, while continuing to fund what were, in retrospect, less valuable programs." How can we understand such a situation?

The relative stability in arms production results from armed forces' wish to maintain production lines that are considered as crucial for national security. Since they are responsible for national security, armed services may have an industrial and technological base at their disposal to respond to an emergency. As a result, some production units represent a strategic resource and must be preserved. "The Defense Department would find it risky and even reckless, notes Kurth (1993, p. 308), to allow a large production line to wither and die for lack of a large production contract". This is the reason why armed forces have sometimes launched new productions when a major program ended to avoid closing a unique and essential capability, even though such systems do neither provide path-breaking innovations nor fill a crucial lack of equipment.

This "follow-on principle" (Kurth, 1972) has two main consequences: a relative stability of the main arms-producing firms, and a technological continuity–resulting from both firms' lobbying and armed forces' conservatism. This explains why the military-industrial complex "has endured for several decades, in some cases dating back to the Second World War, despite the ebbs and flows, the booms

[7] Cour des Comptes.

[8] National Audit Organization.

and busts in defense spending" (Kurth, 1993, p. 307). Such a system constitutes a truly high barrier against technological disruptions and the introduction of new, alternatives defense systems… as long as the tension between available weapon systems and operational needs is not too strong. "The striking fact about the post-Cold War period, mergers and acquisitions notwithstanding, is that essentially all the military aircraft, armor vehicle, and warship building lines opened at the end of Cold War stayed open and productive", explains Sapolsky (2002, p. 35). Similar conclusions could be drawn in most European countries.

Such a bias induces a tacit agreement with defense firms that promote the renewal of existing systems–relying on assets, technology and know-how they master. This strategy can be useful to maintain the defense industrial and technological base, but it has strong negative effects especially in an age of uncertainty and geopolitical evolution. Indeed the follow-on principle favors existing systems against new ones, which do not have the same backing from firms, armed forces and decision-makers for economic, operational and political reasons respectively… Moreover such "follow-on" programs require huge credits and then reduce the available budget for other programs. Here the eviction effect might be strong (and often it is), especially when a less clear geopolitical context undermines the justifications of defense expenditure in budget debates.[9]

Second, the technology-centric paradigm leads armed forces and the industry to look for solutions which appear quite expensive and not optimal with regard to operational, technical and budgetary dimensions. Iraq and Afghanistan operations give a good illustration of such a trend.

As mentioned before, armed forces have faced new threats for which existing capabilities were not fully adapted. Thanks to the massive increase of its budget, The Pentagon has been able to launch new, disruptive programs. Nevertheless, a closer look reveals that choices favor the reproduction of Cold-War program targeting.

In fact, the Pentagon picked up solutions that are technology-intensive, relying mostly on unproven technology and architecture. Two examples that illustrate this trend: first, the Pentagon spent billions of dollars to develop counter-IED devices[10] and yet most of these programs did not deliver expected outcomes (even though some R&D investments were able to reduce risks, at least in Iraq). Similarly, in order to reduce the sniper threat in Afghanistan, the Pentagon promoted the XM25 Counter-Defilade Target Engagement Systems, which appears as a "technological tool" not fully adapted for operational deployment and not fully reliable.

There are many examples of technological over-specifications in defense programs in the United States (For instance, does the U.S. Air Force needs the F-22?) and in major arms-producing countries. The failure of NIMROD in the United Kingdom illustrates a similar situation, as well as FELIN electronic systems for infantry in France.

[9] "Democracies, comments Sapolsky (2001, p. 34), are motivated to buy weapons for what can be best expressed as combinations of survival panics and desire for pork […] Without an acknowledged and believable enemy nearly all weapon purchases tend to look like the distribution of pork to most outside and even some inside observers."

[10] Improvised Explosive Devices.

Even though technology-driven solutions can deliver capabilities for certain threats, it appears that they mainly follow an industrial model where armed forces look for advanced technologies and where the industry is organized to deliver such high-tech systems. This interactive model leads to today's troubles (technological underperformance, unmanageable costs), and it explains why arms-producing countries allocate such a large share of their defense spending to R&D. This does not mean that defense R&D is unnecessary, but the way it is used could be significantly improved to increase its output and reduce its costs (Oudot and Bellais, 2008).

2.3 The security market as a substitute for defense firms

As defense budgets are bound to decrease in forthcoming years, the ability of the defense industry to preserve its business model will be challenged. It appears that this industry has already looked for substitution markets, and it has deeply invested in the security market. This trend was obvious in the United States, when the Bush Administration created the Department of Homeland Security and gave it billions of dollars, mainly to procure systems in the same way the Pentagon does.

It is also interesting to analyze how the defense industry has influenced the structuring of the security market in Europe (Boulanin and Bellais, 2011). Indeed, even though this market is smaller than the American one, its emergence demonstrates how defense firms try to sustain their technology-centered economic model by duplicating it in alternative markets.

In 2003, following the release of its security strategy "For a Secure Europe, in a better world," the European Commission decided to start a research program on security. As part of the program, the Commission gathered a "Group of Personalities," whose role would be to identify needs and research priorities and provide concrete recommendations for the design of an ad hoc research program. This group was mainly composed of defense actors from both public institutions and the industry, including four main European defense firms (EADS, BAE Systems, Thales and Finmeccanica).

Arms-producing firms have been ostensibly associated with the agenda setting process and their influence has been remarkable if one considers recommendations formulated by the Group of Personalities. First, the Group of Personalities clearly promotes technology as a central component to the EU's security strategy, "as a force enabler for security in Europe." The key argument being the following: "Technology itself cannot guarantee security, but security without the support of technology is impossible" (Group of Personalities, 2004: 6). Such promotion of technology is typical of the intellectual paradigm that dominates the defense sector. For example, in the American context in particular, the defense industry offers to respond to each kind of threat with a specific and adapted technology.

Secondly, the report of Group of Personalities underlines that many possible synergies could be found between civil and defense industries (Group of Personalities, 2004, p. 12). In terms of industrial know-how, some military technologies have found some civilian commercial applications and on the other hand, military network-centric systems are largely developed on civilian commercial technologies. The technological needs of police and military forces are also said to be increasingly overlapping (Group of Personalities, 2004, p. 12).

This report takes, for instance, the case of UAVs, suggesting that they can be used both for border surveillance by customs authorities and crisis management missions or surveillance missions carried out abroad by military forces. Articulating that there is more and more of a "continuum" between the technological base of defense and civil security applications, the Group of Personalities recommended to the EU to support a greater integration of defense and security technologies, in particular by favoring the development of sophisticated security goods and services and by taking specific measure to support the European defense industrial base (Group of Personalities, 2004: 20).

These recommendations, which are largely favorable to the defense sector, were by and large retained by the Commission and integrated into a policy paper setting the agenda of the security research program entitled *Security Research: The Next Steps* (European Commission, 2004). The participation of the defense industry in shaping the European program did not come to an end with the agenda-setting phase. Arms-producing firms took part in developing the research program itself.

One of the final recommendations presented by the Group of Personalities, in its report was indeed to set up an advisory board. As for the Group of Personalities, the private-sector side of ESRAB[11] was largely composed of arms-producing firms, mostly the ones sitting at the Group of Personalities. Recommendations addressed by ESRAB regarding the 7th European R&D Framework Program (FP7) had undertones of a remarkable "defense approach."

For each of the four identified key security missions (protection against terrorism and organized crime; border security; protection of critical infrastructure; and restoring security in crisis situation), ESRAB recommended to tune the research agenda according to a capacity-based approach (ESRAB, 2006, p. 6). This concept was directly borrowed from defense. ESRAB pointed out two generic objectives: respond to security needs and develop the global competitiveness of European technological supply (ESRAB, 2006, p. 6).

The defense industry's footprint on the development of this research program is clearly visible. The capacity-based approach that structures the research agenda recalls to a great extent the logic that dominates arms procurement in the United States and European Union. Consequently, it is not fundamentally surprising to note that the actual implementation of research program largely benefits to arms producers. Looking at the various projects funded under the framework of the Preparatory Action for Security Research (PASR 2004-2006) and FP7, arms-producing firms seem to have benefited to a great extent from allocated research credits.

Out of 24 projects funded under PASR, 17 were led by firms operating mainly in the defense sector. EADS, BAE Systems, Finmeccanica and Thales, the four firms sitting on the Group of Personalities, were here highly represented (Hayes, 2004).

One can make a similar appraisal by looking at projects funded under FP7. Even if the ratio of projects led by arms-producing firms is lower than under PASR, the defense industry remains a pampered beneficiary of allocated credits. For instance, out of the 45 projects funded in 2009, 17 were led by firms operating mainly in defense, and 5 were led by firms operating mainly in security sector. One can also note the participation of other non-industrial defense related agents, such as state defense research agencies from the Netherlands (TNO) and Sweden (FOI).

[11] The European Security Research Advisory Board.

The defense industry has played a central role in shaping and monitoring the EU's security research program. There is also little doubt that security-related R&D can appear as an alternative funding channel for European arms-producing countries that need to support their defense industrial bases. On the other hand, security markets related to border security or counter terrorism represent interesting opportunities in the context of a declining defense market.

CONCLUSION

Technology has been essential to military capabilities since World War II. If this trend characterized particularly the Cold War, defense R&D has maintained a central role after the fall of Berlin Wall. This demonstrates that the technology-centric paradigm in defense does not translate only to the specific era of East-West confrontation alone, but represents an essential feature of defense in the twentieth and twenty-first centuries due to uncertainties surrounding international relations.

Nevertheless this fact does not determine whether defense R&D is effectively employed in the most effective manner. Indeed this technology-centric paradigm favored the development of a high-tech defense industry, and these firms appear to try to preserve their "business model" rather than reshuffle this model to adjust to armed forces' current needs. Such hysteresis effect is perceivable when analyzing the emergence of a security market, which has been structured by some defense firms to promote a technology-centric approach.

Trends in defense and security markets highlight the bias possibly introduced by firms when they are able to structure such markets. This leads to question how such state-managed and state-centered markets can be regulated, where competitive pressures cannot be the only driver to avoid manipulation. Indeed, defense and security constitute specific markets as they are not competition-driven markets. Therefore such markets require an ad hoc regulation, preserving an industrial base whilst keeping firms under control.

Beyond administrative regulation, the need for reintroducing democratic processes into the decision loop should be raised. Is it acceptable that critical decisions such as defense spending and military capabilities be delegated to experts and de facto exclude citizens from decision-making because of the technicality of such choices? Whilst technology remains critical to provide adequate capabilities to armed forces, the effectiveness of public spending and the ability to deliver the right capabilities on time require giving citizens and political decision-makers adequate tools to oversee proposed solutions and investment choices.

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