

Carlos Martí Sempere

Doctor in International Security. Instituto Universitario General Gutiérrez Mellado.

E-mail: cmartise@isdefe.es

AN EVOLUTIONARY VIEW OF DEFENCE

Abstract

This article analyses the defence case from the perspective of evolutionary economics. To this end, the key elements of this theory have been applied to the issue of defence; in other words, to the development of military capabilities for the purpose of efficiently protecting society from external threats within a framework of uncertainty and bounded rationality of the actors involved. The paper describes the evolving way through which such capabilities are developed, including the means required for their functioning. Finally, we present the conclusions drawn from this analysis together with its resulting practical implications.

KeyWords

Evolutionary economics, military capabilities, technology, industry.

AN EVOLUTIONARY VIEW OF DEFENCE

I. INTRODUCTION

Defence is an activity whose goal is the protection of national interests, whatever these might be. One of its essential elements is its coercive power to influence the intentions and the behaviour of a potential adversary and thus preventing that such interests are compromised. Even though this coercion may take on many forms, such as political or diplomatic sanctions, a particularly important one is the use of violence, traditionally the remit of the armed forces and the Ministries of Defence.

This article looks at how to obtain the military capabilities supporting such a mission from the perspective of evolutionary economics. An analysis of this kind sheds new light on the subject and allows us to untangle some of the problems associated with an efficient management of defence, that is to say, enabling these capabilities to provide the greatest security at the lowest cost. We will see how these capabilities develop endogenous processes of change that alter the structure, procedures and means employed in defence.

In order to meet this objective, the article has been organised in the following manner: firstly, it briefly summarises the key concepts of evolutionary economics. Secondly, it examines two types of methods or technologies used by society to deal with the problems that interfere with the achievement of its objectives. Thirdly, it analyses how the armed forces obtain military capabilities. Fourthly, it examines how to obtain the means required for these capabilities, an activity in which industry plays a key role. In fifth place, the consequences of this way of proceeding are discussed and the most salient problems highlighted. In sixth place, it examines the practical implications. The article ends with some brief conclusions.

2. KEY CONCEPTS OF EVOLUTIONARY ECONOMICS

Before proceeding with a description of the acquisition of capabilities, it is interesting to examine the origin and key concepts of this theory. Thorstein Veblen, Joseph Schumpeter and, to a lesser extent, Frederick Hayek were the precursors of this theory, which first came into being at the beginning of the twentieth century. However, it was in the sixties when it gathered substantial momentum thanks to the contributions of academics like Richard Nelson, Sydney Winter, Kenneth Arrow, Giovanni Dosi, John Metcalfe, Richard Langlois, Joseph Stiglitz or Herbert Simon, to name its most prominent advocates.

Two aspects are key to this theory.¹ The first is that it does not presume completely rational behaviour from the actors, as it considers their knowledge of reality to be imperfect.² In other words, this theory considers a bounded rationality of the agents, according to Herbert Simon, due to their cognitive restrictions in processing information,³ which leads them to an incorrect understanding of reality and inadequate decision making. Moreover, the most efficient economic decisions can be influenced by social or institutional factors. This means that to bring about a better response or greater efficiency for solving a need requires a lengthy and costly process of discovery and learning (mistake-ridden).

The second aspect is its dynamic approach, which views the present situation as fruit of the past and how it has evolved. In this sense, it is a theory which examines how variations of the current situation are produced and the mechanisms whereby some of these variations abide and disseminate, while others just disappear.

In both aspects, this theory differs substantially from neoclassical economics centred on the analysis of steady-state situations in a framework of perfect competition where the actors have enough knowledge to make decisions that maximise their utility and where history is irrelevant to explain what is happening. Nevertheless, the evolutionary approach allows for the clarification of phenomena which are hard to explain with the tools of neoclassical theory.

Evolutionary economics can be seen as a theory of how society learns to acquire capabilities to better face the problems related to the achievement of its objectives, by developing improved methods. In many instances this learning ends up converging in certain repertoires or behaviours (routines) characterised by higher efficiency. This process is carried out through temporary and imperfect (or less than optimal) adaptations, based on the opportunities and restrictions offered by the context, and tend to be systematically accompanied by a large number of errors, attempts and discoveries.⁴

1 A brief description of this theory can be found in Dosi, Giovanni y Richard Nelson. "An introduction to evolutionary theories in economics." *Evolutionary economics*, 1994: 153-172. A more extensive explanation is available in Nelson, Richard, and Sydney Winter. *An evolutionary theory of economic change*. The Belknap Press, 1982.

2 The complex nature of reality in which multiple actors intervene, means that it frequently behaves in a non-linear and random fashion, given the different feedback from the actors (positive and negative) whose interaction could lead either to a stable situation or an unstable or random situation. This means that reliable predictions are frequently difficult to obtain.

3 This is due to humans' limited computational powers often based on incorrect mental models or constructions. On this issue, see Simon, H. A. *Rational decision-making in business organizations*. Nobel Memorial Lecture. Stockholm. 1978.

4 Dosi, Giovanni y Richard Nelson. "An introduction to evolutionary theories in economics". *Evolutionary economics*, 1994: 153-172.

In other words, this theory analyses the cumulative process through which humans adopt the means in order to reach their ends.

This learning process, whereby a new capability is obtained, is constructed from the present, that is, by introducing changes to current capabilities. The point of departure and the route followed in the exploration determine the final result. The search can be dictated by heuristic methods,⁵ conjectures with a greater or lesser foundation or even simply by pure chance. In this context one can achieve a locally optimal capability; however, better capabilities might exist, but are not achieved because they have been unexplored. This can be seen more clearly in the example of figure I which shows the usefulness of a solution (axis Z) with regard to two internal parameters (axes X and Y). The search for the best option, if carried out in the lower left-hand quadrant, can only manage to achieve a local optimum, while it is necessary to move to the centre of the figure in order to obtain a global optimum. Thus the final result is conditioned by the exploration route selected.⁶

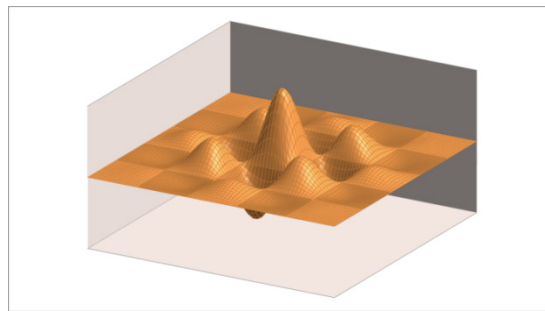


Figure I. An example of the roughness of the innovation landscape.

This process of change remains permanent for various reasons. In the first instance, because historic changes in the socioeconomic system tend to impose exogenous changes on the economic context and new, quite unfamiliar problems for the actors differing from those of the past.⁷ Secondly, because the proper process of adaptation can end up affecting its own ends and, therefore, these will ultimately vary.

⁵ Although logic and deduction are especially useful when it comes to intuitively sensing the correct paths, they are not enough and at some stage it is necessary to test whether the hypotheses are correct.

⁶ On this subject, see David, P. A. "Path Dependence, its critics and the quest for 'historical economics'" in *Evolution and Path Dependence in Economic Ideas: Past and Present*, edited by P. Garrouste and S. Ioannides. England: Edward Elgar Publishing, Cheltenham. 2000.

⁷ Nelson, Richard. "¿What enables rapid economic progress: what are the needed institutions?" *Research Policy*, 2008: 1-11.

Thirdly, because the impossibility of guaranteeing the optimal nature of these capabilities means that theoretical opportunities for discovering better ones will always exist.

Figure II serves as an example. If a global optimum was found in figure I, a change of geostrategic context could cause the optimum to be displaced to the right, so another solution must be searched for. An example of this situation could be the development of the *Eurofighter* aircraft initially designed for facing the Warsaw Pact, a threat that disappeared with the dissolution of the Soviet Union. A similar situation arose with the development of the frigate F-100, originally intended for antisubmarine warfare and which, with the disappearance of the Mediterranean V Squadra was reoriented towards an anti-air frigate on the grounds that the main threat would come from the air. Similarly, the signing of the Treaty banning chemical weapons rendered worthless the large arsenal of this class of weapons accumulated by the superpowers during the Cold War, and shifted the focus towards protection against attacks from rogue states and terrorist groups.

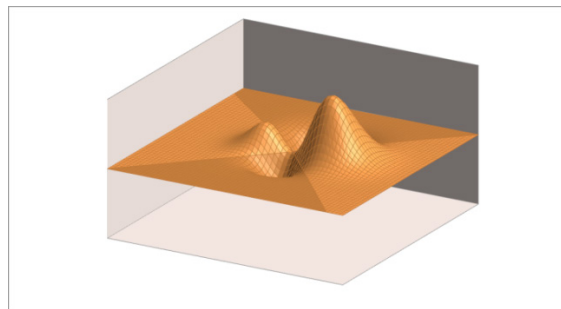


Figure II. An example of the roughness of the innovation landscape.

Conceptually, this theory stems from Darwin's theory of evolution, while displaying certain differences. Here the capabilities –presented in the form of an organisation, procedures and artefacts– constitute the genetic material around which mutations are produced and via a selection mechanism allow organisations to achieve their objectives more easily. In effect, if these changes are positive, that is, if they facilitate the achievement of said objectives, they will abide and disseminate, while if they hinder it, they will end up disappearing over time.

This theory is also indebted to the advances in information systems, which have enabled the modelling and analysis via simulation programmes of the complex phenomenon of economic change. The results obtained have confirmed the validity of the evolutionary models reproducing situations similar to those observed in real life.

3. PHYSICAL AND SOCIAL TECHNOLOGIES

The methods, techniques and procedures which this process of endogenous change undergoes can be classified in two relevant types.⁸ The first is known as physical technologies, in other words those methods whose description can be abstracted from the division of labour.

The second is called social technologies, that is, those related to the division of labour and the coordination of the actors.⁹ The latter are required when the actions and interactions of the agents have a significant influence on the final result attained. These technologies give rise to institutions and are formally reflected in laws, norms, rules, mechanisms and government structures, and common in habitual forms of organisation and negotiation.

The joint evolution of both technologies is required in order to achieve better capabilities. For example, certain social technologies such as state organisation, tax collection, or credit institutions were essential for financing the military campaigns of Charles V and Philip II, in a framework in which firearms substantially increased the cost of military campaigns.¹⁰ In the French revolution, the concept of a nation at arms made possible universal recruitment or *levée en masse*, which proved fundamental in sustaining the extensive military campaigns of Napoleon Bonaparte in Europe. And the development of the concept of the firm as a large unit for producing goods during the industrial revolution of the nineteenth century became fundamental in supplying the great armies mobilised in the First World War.

On the other hand, the failure of either one of them could cripple a capability, as occurred, for example, with the army of Saddam Hussein in the first Gulf War, where, despite being equipped with top-quality Soviet materiel, it failed to demonstrate efficiency in the field of operations, due to an absence of professionalization and a rigid and authoritarian structure with very little room for initiative and for a quick response to unexpected circumstances. Another example was the poor performance of the Argentinian ground forces in the Falkland Islands due to a lack of cohesion between the different levels of their units.

8 *Ibid.*

9 Nelson, R., y K. Nelson. "Technology, institutions, and innovation systems" *Research Policy* 2002: 265–272.

10 North, Douglas. *Institutions, institutional change and economic performance*. Cambridge University Press, 1990.

Similarly, in comparison with the Germans, the allied forces rarely displayed the organisational skills and flexibility to make full use of the resources at their disposal in World War II.¹¹

4. THE PROCESS OF OBTAINING MILITARY CAPABILITIES

A detailed observation of how military capabilities are obtained shows that this is a process with marked evolutionary characteristics. With the development of organisational structures, operations procedures (doctrine) equipment and systems, armies develop capabilities that make the difference with respect to their potential adversaries.

This process takes place on the basis of variations of existing capabilities and the choice of alternatives that perform better in the field of operations. Those which are best suited tend to spread and expand, while those functioning poorly tend to be used less and finally disappear altogether. For example, defence based on medieval castles was rendered obsolete with the development of artillery and the use of planes to locate and attack the enemy fleet with bombs and torpedoes, even before their sighting, boosted the spread of aircraft carriers and ended up replacing battleships as the flagship of naval fleets.

The air defence developed by the United Kingdom at the beginning of World War II is another example of military capability. It consisted of a command centre, radar equipment to monitor the airspace, a communications system, and air fighters equipped with radio to intercept and repel the *Luftwaffe's* air attacks. The deployment of this capability required key technologies such as detection and early warning equipment via radio-electric signals, as well as ground-to-air and air-to-air communications systems in the UHF band.¹²

A third example was the development of amphibious operations during World War II in the Pacific enabling a rapid landing of troops onshore under opposition. This new form of operation required both the development of a doctrine for this kind of operations as well as the development of landing craft and amphibious tractors adapted from civilian designs.¹³

¹¹ Millet, A. R., W. Murray, and K. H. Watman. "The Effectiveness of Military Organisations". *International Security*, 1986: 37-71.

¹² The initial detection equipment was based on sound, but their limited range meant that they were replaced by the use of radio-electric signals.

¹³ Martí, Carlos. *Tecnología de la defensa. Un análisis de la situación española*. Madrid: Instituto Universitario General Gutiérrez Mellado, 2006. p. 139.

The process of procuring these capabilities accounts for a major part of the resources allocated to defence. Thus, for example, in 2013 the USA invested \$69,400 million in R&D, according to the Department of Defence. This figure corresponds to 9,95% of its budget and represents half of public expenditure in R&D according to Eurostat data, as can be seen in figure III.

Let us now take a closer look at the three key elements of evolutionary economics within the framework of obtaining military capabilities: the generation of variety, the selection process and the replication or dissemination of a capability.

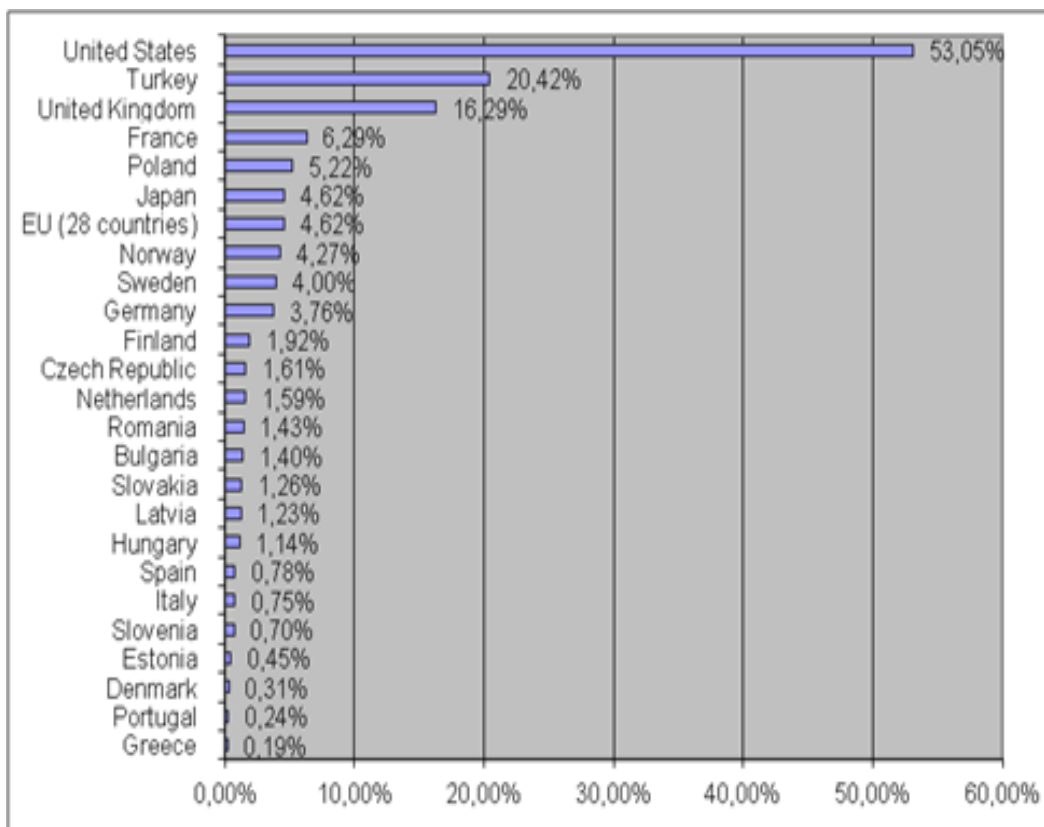


Figure III. Percentage of outlays of defence R&D (2013). Source: Eurostat.

4.1 The generation of variety

Generating variety is a deliberate process rising from the shortfalls and poor efficiency of the current military capability, which encourages experimentation with new ways of carrying out operations. For example, the need to communicate rapidly and reliably gave rise to the use of flags, standards and messengers. But their limited range or slow transmission led to their replacement with optical telegraphs at the end of the eighteenth century. The impact of meteorology on the performance of

these telegraphs, meant that these were in turn replaced by electric telegraph in the mid-nineteenth century, and finally by telephone lines permitting voice transmission at the end of that century. Later, the development of wireless telegraphy and the radiotelephone in the twentieth century did away with the costly and rather inflexible infrastructure of past communications methods.

Incentives to search for new alternatives are conditioned by diverse factors. Firstly, these tend to be greater where significant deficiencies have been identified. This typically occurs in the wake of a military failure seriously affecting national interests, such as the German defeat of the First World War, which forced them to revise land operations and sowed the seed for their major successes in the next War. Secondly, these incentives grow when the risk of armed conflict is greater. Thirdly, the incentive may arise out of internal competition between different corps of an army, or between services in order to increase their overall leverage in terms of defence. This, for example, could be the case of the three US services in their struggle for nuclear capabilities during the Cold War, which ultimately all of them achieved.

On the other hand, the incentive to promote change is probably not so great where capability procurement investments have been considerable and are likely to be lost to a certain extent if the change comes about. The very same occurs when the utility of the change is surrounded by uncertainty, or when the new capability demands considerable organisational changes, which are expensive to implement, that is, when social technologies are also required. This explains the inertia within the Armed Forces when it comes to modifying their capabilities and the slow pace that can be observed in the deployment and consolidation of a new capability. This resistance of armies to new arms, procedures and organisational structures is borne out historically.¹⁴

The gestation of a superior capability is arduous in any case. Capabilities cannot be easily evaluated unless they are put to the test against a capable adversary, which is not always possible. Thus, the *Patriot* missile had already been part of the US army's inventory for six years when it failed on its first combat test during the Gulf War.¹⁵ In peace times possibilities are confined to manoeuvres and testing which, while they produce information, are not always carried out in a similar environment as

¹⁴ See, for example, Millet, A. R., W. Murray, and K. H. Watman. "The Effectiveness of Military Organisations". *International Security*, 1986: 37-71; y Elting E. Morison, "Gunfire at Sea: a case study of innovation" in id., *Men, Machines and Modern Times*, Cambridge, MA: MIT Press, pp 17-44. But perhaps the best known case is the Japan of Tokugawa which prohibited firearms in an attempt to curb the monopoly of violence.

¹⁵ Alic, J. A. *Trillions for Military Technology. How the Pentagon Innovates and Why it Costs so Much*. New York: Palgrave MacMillan, 2007. p. 20.

Nelson, Richard. "The role of knowledge in R&D efficiency". *The quarterly journal of economics* (O), 1982: 453-470.

the battlefield. Besides, the economic resources for exploring solutions, such as the elaboration of new doctrine, testing in the field of operations and the development of new equipment and systems, are considerably smaller. All of this complicates the gestation of variety.

This exploration is also conditioned by the knowledge available, as greater scientific (and technological) knowledge permits more precise conjectures about the effects of the possible alternatives, rather than more random searches that would take up additional time and resources. Thus knowledge provides for powerful heuristic-based search¹⁶ and paves the way towards finding new solutions.¹⁷ An example of the contribution of knowledge towards the development of significant advances for artillery would be the progress of the physical theories of Galileo and Newton.

In this sense, the development of capabilities tends to cost more the further the new procedures move away from recent practices, since these cases there is less knowledge and a higher probability of committing errors. Thus the tendency is to implement incremental changes onto existing technological and institutional designs. Furthermore, given that the changes introduced tend to raise internal conflict, established routines are maintained, insofar as possible, in order to avoid the costs associated with change.¹⁸

It is worth noting that the development of new capabilities and the integration of new arms within the armed forces are not always well received by the armies, in particular when this affects values such as assigned resources, commitments and responsibilities, status within the organisation¹⁹ or the social environment of a military organisation.²⁰ This was the case with the introduction of battle tanks, planes, aircraft carriers and submarines in many nations.²¹ And it could be the case with new systems like UAV planes, replacing manned surveillance or combat aircraft. This resistance to change can slow down or impede the implementation of efficient forms of operation and a greater coercive capability of the armed forces.

16 Nelson, Richard. "The role of knowledge in R&D efficiency". *The quarterly journal of economics* (O), 1982: 453-470.

17 Greater knowledge permits focusing on the search for options that will improve military capabilities, by enabling the identification of correlations between variables of design and performance or in the design of tests. See Rosenberg, N. "Science, Invention and Economic Growth". *The Economic Journal*, 1974: 90-108.

18 Nelson, Richard. "The role of knowledge in R&D efficiency". *The quarterly journal of economics* (O), 1982: 453-470.

19 Downs, A. *Bureaucratic Structure and Decision making*. Memorandum RM-4646-1-PR. Santa Mónica, CA: RAND. 1966. p. 106.

20 Millet, A. R., W. Murray, and K. H. Watman. "The Effectiveness of Military Organisations". *International Security*, 1986: 37-71.

21 *Ibid.*

4.2 The selection process

In the area of defence the process of selection is carried out internally, or bureaucratically, in contrast with the selection of civilian products and services where the market mechanism generally tends to play a significant role. Decision-making in these cases is implemented in a hierarchical fashion within the organisation itself. Nevertheless, this method is imperfect, as evaluation can be contaminated by the particular interests of the actors in charge of the selection process. This is less likely to occur when market mechanism is employed, where the additional perception of a large number of consumers guarantees greater impartiality and reduces bias in the selection of the most useful products.²²

The cases of failed selection are multiple. A paradigmatic example was the decision to employ strategic bombers in World War II on the western front with a view to bringing the war to a close. The exercise resulted in the loss of US bombers and pilots, which was not rewarded by the limited effects of their attacks. The restriction of having to fly on straight and levelled paths in order to have some hope of bombs falling onto their objectives meant that their planes were vulnerable both to fighter planes and anti-air artillery fire.²³

4.3 The dissemination of a capability

The expansion of a new capability tends to take time. At the outset, the capability is immature and its benefits not altogether clear, which can slow down the initial process. However, as it becomes clear that it surpasses those currently employed, the process of change accelerates as it is displayed in figure IV.²⁴ This is what happened, for example, in the evolution of firearms on the battlefield. Initially, arquebusiers operated alongside pike men, but as these arms improved and their efficiency was verified, the number of pike men declined with the corresponding increase of musketeers and fusiliers in the columns, until the invention of the bayonet put an end to the pike men. This was a lengthy process and lasted around 250 years.²⁵

22 Nelson, R. R. and Winter, S. "In search of useful theory of innovation". *Research Policy*, 1977: 36-76, p. 68.

23 Alic, J. A. *Trillions for Military Technology. How the Pentagon Innovates and Why It Costs So Much*. New York: Palgrave MacMillan, 2007. p. 21, 23, 31 y 156.

24 Geroski, P. A. "Models of technology diffusion". *Research Policy*, 2000: 603-625.

25 Martí, Carlos. *Tecnología de la defensa. Un análisis de la situación española*. Madrid: Instituto

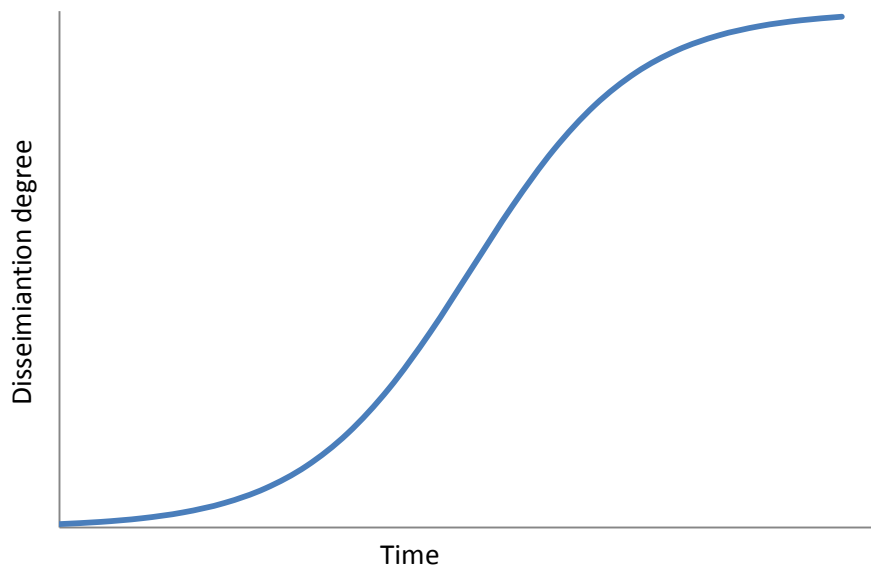


Figure IV. Typical curve showing the spread of a technology.²⁶

This slow and gradual spread is in part due to the limitations of the armed forces in absorbing the required knowledge for copying or imitating the new capability, as well as the associated economic costs which, while not quite as great as the initial innovation in itself, are nevertheless significant. This imitation process requires various adaptations and changes until a satisfactory level of efficiency is achieved. In practice, this absorption process has proved quite limited, as can be seen from the aforementioned case of Iraq, probably due to the difficulty of acquiring the knowledge of the physical and social technologies of any military capability including the tacit knowledge they contain.²⁷

The process of dissemination and imitation can be accelerated among allies when the use of the same capabilities provides additional advantages for all, in other words, when these generate positive external effects. This is, for example, the case of the Atlantic Alliance member states, which can achieve considerable advantages using a common doctrine and resources such as arms and equipment.

This process continues until it has extended so far as to render the original advantages too small, in comparison with those employed by other armies, on account of their assimilation or improvement by the latter, which can slow down their dissemination and promote the search for new and different capabilities.

As a consequence we can say that the evolution of a capability is interactive and is dictated both by what an army does and how its potential adversaries behave.

Universitario General Gutiérrez Mellado, 2006. p. 73 and following.

²⁶ Geroski, P. A. "Models of technology diffusion". *Research Policy*, 2000: 603-625.

²⁷ Polanyi, M. *The Tacit Dimension*. University of Chicago Press. 1966.

5. THE PRODUCTION OF DEFENCE MEASURES

The implementation of military capabilities requires material means, such as combat vehicles, planes, frigates and command and control systems. These means determine their utility in the field of operations. Thus, for example, command and control systems permit a greater coordination of operations and greater returns from the armed forces; land, air or naval platforms permit the movement of troops to specific points where their intervention is required; sensors enable the early location and detection regarding the situation and the intentions of the adversary, and guided weapons systems can assist in neutralising targets in the field of operations in a timely fashion and with minimum damages to the environment.

These means shape to a large extent the organisational procedures and structures of capabilities. Thus, for example, the railway was a means that revolutionised the logistics of the armies of the late nineteenth century as it enabled the cheap transport of a large volume of materiel to the front lines. Similarly, the appearance of unmanned aircraft vehicles (UAV), advanced sensors and communication systems have substantially modified the way in which intelligence is obtained and distributed in the field of operations.

As we have seen, the need for armies to possess capabilities superior to those of their adversaries, is the main incentive for designing and developing the mean whereby military capabilities can be substantially improved. While the armed forces are capable of identifying the precise features required in the field of operations, business enterprise also has a leading role to play thanks to its technological and industrial infrastructure enabling the efficient design and production of such equipment.

In this framework companies must develop advanced products and the required technology for their production. If a firm comes up with a successful design, it can monopolise the market for such equipment, given the difficulty of replacing it with another, as these products tend to be tailor-made for the purchaser. This can guarantee the awarding of their production and improve their productive capacity, enabling an increase in resources available for the development of new R&D activities as well as a stream of income for a prolonged period of time. On the other hand, unsuccessful firms are forced to shrink and if their lack of success continues they may end up abandoning the market.

In this context, the possibilities for businesses to survive and grow are determined by the quality and price of the products and services which they offer in the market. Nevertheless, a firm must take advantage of these opportunities within a framework of financial restrictions governed by cash flow, accumulated profits, or the investors'

hopes of future benefits from the company.²⁸ In other words, the company has to act within a context of risk and uncertainty.

In this field of activity, the Administration and the company invest considerable sums of money. In the first instance funds employed in: defining needs, carrying out viability studies, financing specific research and development projects, evaluating the final product and integrating it with new operational procedures, in order to gain the greatest possible returns from the new means. Secondly, funds are employed to obtain a knowledge infrastructure and the technical means that will allow it to research and develop a final product with superior features. The financing of specific R&D projects and their subsequent development tends to be entire, given that the spill-over effects, that is to say, the reutilization of the technologies obtained in other sectors of the economy are not too significant. Otherwise industry would not have the necessary incentives to fine-tune the new technologies. Figure V clearly demonstrates this. In it we can see the different approximate trajectories of the cash flow of a company for a civilian and military innovation. In the first case, the company investments produce a cost that is only recovered subsequently. In other words, this private investment requires a period of time in order to achieve returns. Meanwhile, in the military sector, there are returns from the outset, once the research project is awarded, although market regulations (and the actual success of the innovation) limit the company's economic benefits from the awarding.

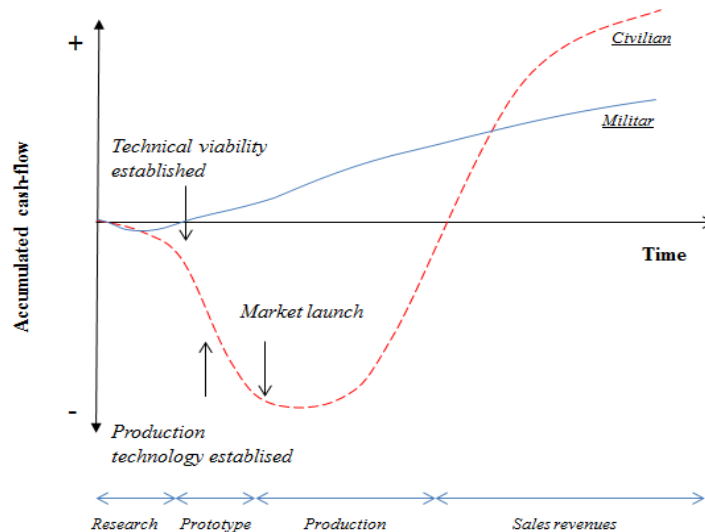


Figure V. Typical cash-flow in the case of civil and military innovation.

Following on from our analysis of the capabilities, let us now examine how the three key elements of evolutionary economics are achieved.

28 Dosi, Giovanni, and Richard Nelson. "An introduction to evolutionary theories in economics". *Evolutionary economics*, 1994: 153-172.

5.1 The generation of diversity

Generating diversity is carried out through research projects that enable the evaluation of the features of architectures and designs deemed most appropriate to sustain a given capability. In this sense, the heterogeneity of the industry permits a widespread exploration of the spectrum, which favours finding the most appropriate technology. Nevertheless, this process may incur negative consequences for certain companies in the form of a failure to meet expectations or errors that nevertheless produce positive externalities such as the reuse of the results by other enterprises or, ultimately, bankruptcy in the case of those who fail to achieve a minimum number of orders.

As is the case in generating capabilities, the search process is conditioned by resources, knowledge and the infrastructure of the firm. This bounds its effective field of exploration and explains why exploration is carried out in areas close to the knowledge base and technological capabilities of the company, based on the developments which have proved successful in the past.

If the search in this local environment does not lead to solutions with a noticeable difference in performance, then it is necessary to look for more distant alternatives which, due to the lack of knowledge about them, increases uncertainty with regard to their ultimate successfulness. Thus, for example, these alternatives can be characterised by a very different architecture, which can cause major organisational problems within the company that may hinder this exploration.²⁹

One way of mitigating uncertainty in these cases is to imitate a successful design developed by another company. However, this process also has its own risks, because this form of imitation is anything but simple, given that not all the related knowledge is available. This is borne out by the failed attempts of many nations in the world to imitate US or European designs in advanced weapons such as combat planes and missiles.

Obtaining a first design offering interesting features constitutes a new point of departure leading to the exploration of new solutions. This process is guided by the identification of unbalances in solutions, which in turn focuses the search at alternative, more efficient designs.³⁰ Thus, for example, improvements in the range of the medieval trebuchet presented the need to improve precision, which was achieved by unifying

29 Henderson, R., and K. Clark. "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms". *Administrative Science Quarterly*, 1990: 9-30.

30 Rosenberg, Nathan. "The direction of technological change: inducement mechanism and focusing devices". *Economic development and cultural change*, 1969, 1-24.

the form and weight of the stone shot.³¹ In the same way, the discovery of firearms increased the capacity for causing damage to the adversary, but the length of time involved in the loading process, which left the shooter vulnerable, led to the exploration of ways to speed up the process and the invention of cartridges, subsequently leading to the automatic load.

The phase involving the search for one design that is clearly superior to others tends to be a turbulent period in which companies attempt to enter into the market offering their designs and prototypes to the armed forces with a view to securing a contract for their development and production. Confirmation of this turbulence is provided by the multiple R&D studies and projects undertaken, only a few of which reach a successful conclusion.³² In this framework, only firms whose designs are selected are able to remain within this market segment.

5.2 The selection process

The selection process still has a largely bureaucratic component. The requirements established by the armed forces constitute the starting point and they are the ones who make the choice from the designs offered by firms. This selection process is subject to review following its development as a prototype and its operational evaluation.

The final design put forward by a company is the outcome of an internal selection process. This process requires the careful selection of the different integrating components so that they largely satisfy the operational needs. This process leading to the adoption of an acceptable and feasible design takes time and is subject to constant errors and reconsiderations.³³

5.3 The dissemination process

The most adequate solutions developed by industry will inevitably be copied by others. But this process is complicated and costly,³⁴ as other firms tend to lack the skill

³¹ *Ibid.*

³² On the elevated number of failed projects in defence see Leitenberg, M. The dynamics of military technology today. *International Social Sciences Journal* 1973, 336-357.

³³ Martí, Carlos. *Sobre la eficiencia en defensa*. Madrid: Instituto Universitario General Gutiérrez Mellado, 2015.

³⁴ Rivkin, J. W. "Imitation of complex strategies". *Management Science*, 2000: 824-844.

and experience to dominate the technologies associated with the new product. As we have seen, this generates inertia in the dissemination process.

In this sense, certain technical advances destroy the competences acquired by companies,³⁵ which demands a process of mastering new technologies. A similar problem arises when the innovation requires changes in the structure of the company or organisation, which, where they are not accomplished, pose difficulties for the supply of new products or services.³⁶ This happens when the architecture of the new product is different and demands the modification of the entire supply chain, from the sub-contractors supplying the subsystems to the suppliers of subsets and components. For example, the transistor brought about the replacement of suppliers of thermionic valves for transmission equipment by manufacturers of semiconductors. Another example was laser telemeters that rendered obsolete the optic telemeter technologies based on triangulation. This “*creative destruction*” effect, as Schumpeter called it, could have a negative impact on the industrial base of less advanced nations whose capabilities could run the risk of become obsolete.³⁷

5.4 The search for efficient production

Once the definitive design has been reached, the company must develop efficient production methods. The new product will require a different manufacturing process, which involves a new organisation, new methods and new equipment replacing those employed previously.³⁸ The development of new methods is often accompanied by a greater division of labour and a greater specialisation, which facilitates greater knowledge and enhanced productivity. The time sequence of the product and processing innovations follows a curve, as shown in figure VI, where one can observe how the innovations of the production process increase as the design of the final product is consolidated and becomes dominant.

35 Tushman, M., and D. Anderson. “Technological discontinuities and Organizational Environments”. *Administrative Science Quarterly*, 1986: 439-465.

36 Henderson, R., and K. Clark. “Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms”. *Administrative Science Quarterly*, 1990: 9-30.

37 Schumpeter, J. A. *Capitalism, Socialism and Democracy*. New York: Harper & Row. 1942.

38 Utterback, James M., and William J. Abernathy. “A dynamic model of process and product innovation”. *The international journal of management sciences*, 1975: 639-656.

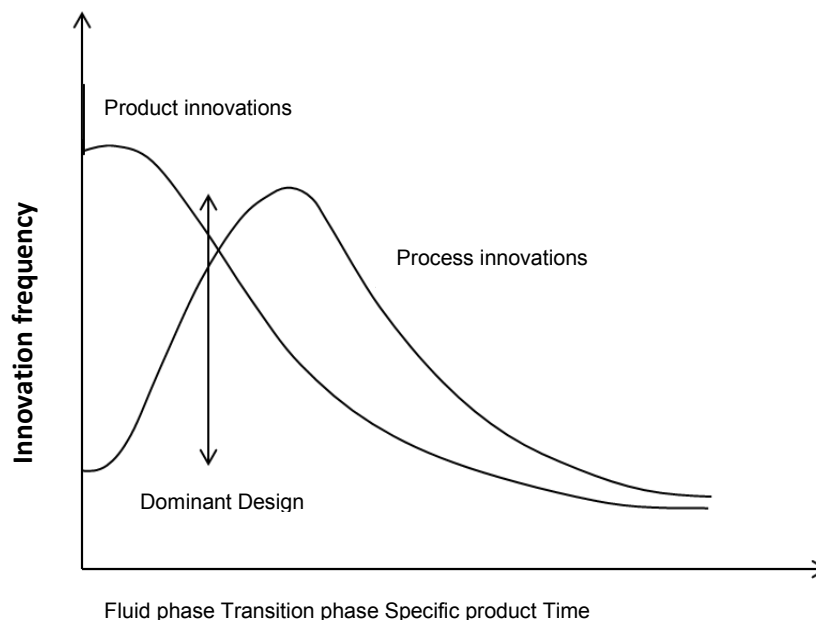


Figure VI. The general gap between innovations of product and of process.³⁹

Given that the key element for success is the innovation of the product, innovations in production are less critical in the sector of defence. In any case, these innovations depend on the volume of production. If this is small, a handcrafted production process could be sufficient, whereas if production is on a large scale this requires the automatization of such processes, whose duration or cost could be considerably reduced.

This innovation also depends on the existing production capacity, its depreciation and the cost of introducing new manufacturing methods. However, given that usually the company is paid on the basis of production costs plus a certain profit margin, the incentives for radical innovations tend to be small, the tendency being to take advantage of the innovations and methods embodied in equipment and methods developed by other companies.⁴⁰

6. DISCUSSION

In the previous sections we have seen how the three basic mechanisms of evolutionary economics -the generation of variety as well as the selection and the replication

³⁹ *Ibid.*

⁴⁰ Pavitt, K. "Sectoral patterns of technical change: Towards a taxonomy and a theory". *Research Policy*, 1984: 343-373.

processes- enable one to overcome the uncertainty and the bounded rationality of the human condition and thus achieve substantially better solutions. Thus, these mechanisms facilitate the continuous adaptive change of society to new contexts in which it will have to operate. We shall now look at the circumstances in which these mechanisms present problems that hinder the achievement of better solutions.

6.1 The generation of variety

The uncertainty inherent in the search process together with the inability of the actors to clearly identify what is better, means that one cannot forecast *a priori* which solution will finally be the winner. For this reason pluralism and competition are important in the search for better solutions. This process of generating variety nevertheless has to face limitations in respect to the resources and knowledge available to the activity, which significantly curtails the exploration tree. This problem is heightened when the means and the number of agents involved is small, as tends to occur with research centres with limited resources or a meagre industrial tissue. In this sense budgetary limitations may leave little scope for exploration and experimentation, while the complexity of the product could mean that only a few companies or consortiums have the necessary cognitive and technological to submit a tender with success. The problem is that if the government lacks the resources to guarantee business to a certain number of companies ensuring them adequate profits, they will not be interested in serving this market, which gives rise to a poor technological and industrial base. In this sense, the profitability of the industrial base is difficult to sustain when demand is very cyclical (in the case of submarines, for example) and delays frequently occur with programmes and payments. This could be the case of the European industry where, despite high levels of productivity, the companies enjoy lower profit levels than elsewhere in the market.⁴¹

This problem could extend to the small and medium-sized business sector. The variety of techniques and knowledge required by defence demands an especially large supply chain. Within this chain, one can find particularly innovative companies, but small in size and with limited financial means. If the main contractors do not open up the tendering process and support their chain on a rigid structure, it is possible for these small firms to encounter insurmountable difficulties in the way of bringing their innovations to the armed forces.

Finally, the problem of generating variety can be exacerbated when, through a lack of coordination between the agents, certain areas are over-explored, while others are left unattended. This could currently be the case with unmanned aircrafts or with cyber defence compared to other capabilities.

41 Hartley, Keith. *The Economics of Defence Policy: A new perspective*. Routledge, 2011, p. 166.

6.2 An imperfect selection mechanism

Secondly, the information available to make the choice could be imperfect. This tends to occur with the evaluation and identification of the causes of lower levels of efficiency than expected in military operations. If information is lacking and the causes as well as the means of bringing about increased efficiency levels cannot be identified readily, wrong choices can be made, as was the case of the air bombings of the World War II mentioned before. A similar problem could arise when the business proposals for a given development are incorrectly evaluated, either through lack of objectivity or, in the case of future projects, unforeseen difficulties were not taken into account.

Another important source of bias in decision-making regarding the evolution of military capabilities can be political, social or cultural factors. One could quote multiple examples. A primary example is the restriction of the budget equally shared across three services (air, sea and land), instead of being based on their real contribution to defence, which would lead to an inappropriate allocation of resources. A second example is the aversion to certain arms, as was the case of the UK regarding submarines in the World Wars, as attacks on civil ships were looked upon as an act of terror. A similar case is the use of arms producing large-scale suffering, such as chemical weapons.

A third example is the use of air attacks on the civil population, equally a subject of debate for some time. A fourth example would be the kind of operations used in the Vietnam War where the American military forces could have increased their tactical efficiency through closer engagement with the enemy, instead of relying on indirect fire. However, the price could probably have been greater casualties and less political effectiveness.⁴² A final example is the awarding of projects to certain firms in order to promote regional development, even if they are not necessarily the most needed.

Choice can also be biased when the private and social benefits or costs of a given option differ substantially. In this case, the decision-maker may choose an option that is not necessarily the best from a social point of view. Thus, for example, a new capability could require the development of new organisational structures, which tends to be a source of conflict, as commented previously, and tends to generate opposition to the development of a new capability.

A similar example could arise when a company offers to supply a product for defence with an improper performance-price ratio. This case can easily be found where there is a lack of competition and the absence of a yardstick for comparing options, while an aversion to risk-taking means that a given product is preferred despite the disproportion between performance and cost.

⁴² Millet, A. R., W. Murray, and K. H. Watman. "The Effectiveness of Military Organisations". *International Security*, 1986: 37-71.

In the same way, if the process of selecting firms is not functioning correctly, by rewarding or penalising firms according to their performance, then the efficiency of the sector can be compromised. This is almost certain to occur, as the major difficulty in finding an alternative supplier for the product means that the imposition of sanctions is not easy to apply if it has a major impact on profits and ultimately on the survival of the company. In the end, this would reduce the efficiency of the acquisition process.

An example of this could be when a firm supplying a key product fails to carefully manage its resources, relying almost on the certainty that, should it incur losses, the government would come to its rescue. Such was the case of Rolls Royce, which had to be nationalised in 1971 when the development of the RB211 engine surpassed the costs forecasted.

The selection mechanism itself could tend towards the discrimination alluded to in the phrase: success breeds success. In effect, the selection process may not choose the best solution when one firm offers better initial features yet, having the second solution potential for greater performance but requiring a lengthier development-apprenticeship process until it materialises, which means it could be easily discarded.⁴³

This problem is likely to occur when an option is the first to appear on the market and develops more, thus managing to better adapt to the needs of the user, as we can observe in figure VII where one sees the second technology, with lower initial performance levels than the first, already in an advanced stage of development, which after some time ends up reaching a superior performance. This means that if one does not opt for the second technology, it is probable that this more valuable option will never triumph.

⁴³ This is a further example of path-dependence similar to the one described at the outset of the article.

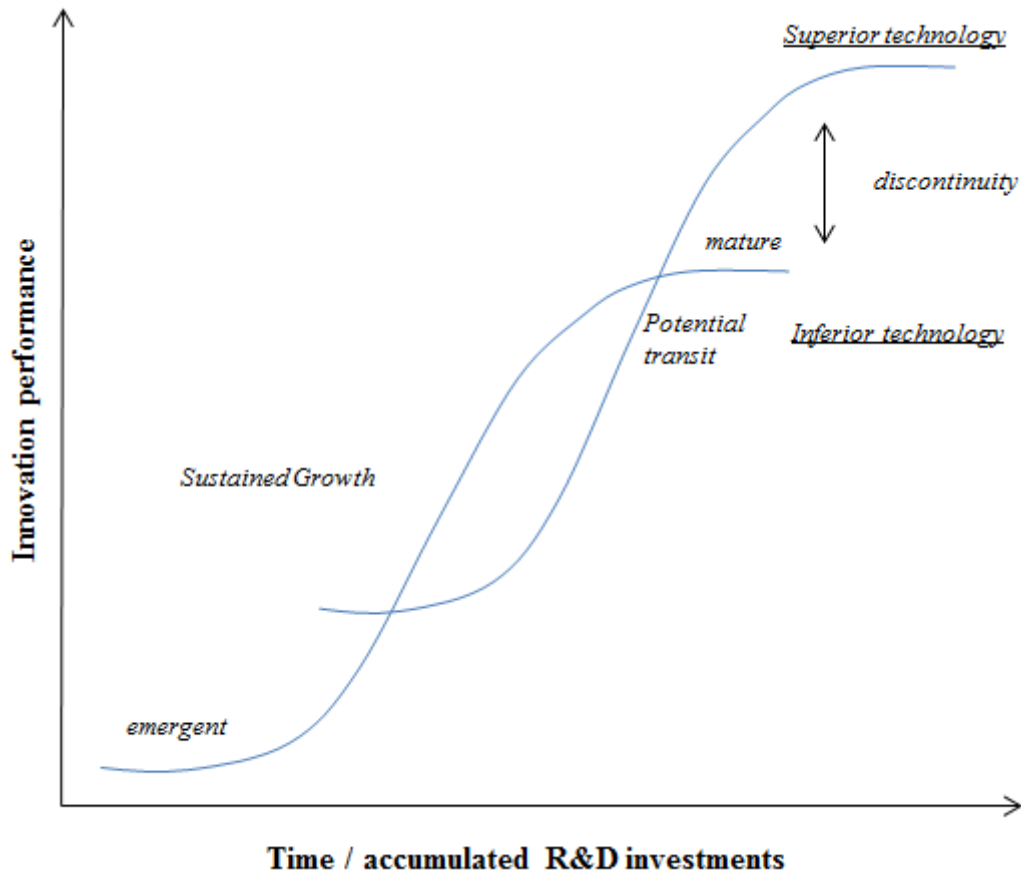


Figure VII. Two innovations with a differing evolution in performance.

This problem is especially important because, given that the competences of an organisation or company is based on accumulated learning, the firms or actors already in the market enjoy advantages over those willing to enter with their new technologies, processes and products (less developed but potentially superior). In a context in which nations hold different defence budgets, industrial discrimination can occur, as firms from nations with greater resources have more funds available for innovation, giving them a competitive advantage over nations with lower budgets and without the capacity to develop their technologies and become market leaders.

6.3 Social technologies

Social technologies play an important role in the procurement of military capabilities. On the one hand they are necessary for the development of the capabilities themselves and on the other they are needed to develop a framework of organisational institutions and structures favouring the evolution of these capabilities.

An example of the first case is the institutional and organisational changes required when technological change generates imbalances in a capability. For example, the technical capability of collecting and distributing information rapidly in the field of operations has had an influence on the organisation of the armed forces. When these means were scarce, armies tended to operate in a more autonomous fashion. On the other hand, when these means progressed (telegraph, telephone) the command control capability of the forces became stronger, permitting a far superior operational coordination.

Nowadays, the huge dissemination of communication and information systems permits access to the information required at any given moment in a decentralised manner, which favours less hierarchical operational structures providing greater scope for self-organisation.

An example of this second case is the especially advanced innovation network in US defence which, together with a wealth of available funding, allows the achievement of significant advances in many capabilities.

However, not all institutions have a positive effect on improving capabilities. This could be the case of lobbying when it compromises the procurement of social benefits by influencing the funding of projects from which only the industry benefits. In this sense, the setting up of independent advisory committees can reduce pressure, within the bureaucratic decision-making process, which characterises a hierarchical organisational structure.

The problem is that the evaluation of the need, or the value, of a particular institution is often very difficult, and tends to be poorly judged.⁴⁴ The reason is that it is often very difficult to classify the effects of a particular institution or social technology from the influences of a broad catalogue of variables affecting the achievement of the objectives of an organisation or firm, or to reliably estimate the costs and benefits to society of a complex set of laws and policies. In other words there is less capacity for analytically comparing institutional alternatives.⁴⁵

This is much simpler with physical technologies, which to a certain extent can be isolated and evaluated in a more controlled experimental environment and isolated from external influences. The weakest link between institutions that can be designed and the behaviours they generate mean that the transfer from a controlled environment to reality does not tend to function well.

44 Nelson, Richard. “¿What enables rapid economic progress: what are the needed institutions?” *Research Policy*, 2008: I-II.

45 In practice, it has been observed that firms have difficulties identifying the common set of social technologies when they have several departments producing the same product, a problem that can also occur within different army units.

The difficulty of obtaining feedback on the performance of social technology, and its supporting institutions, makes it difficult to give it up, once in operation, even if there is little evidence that it is achieving what it is expected to. In this sense, these technologies are more likely to spread by fashion or ideological reasons.

6.4 The dissemination and acquisition of capabilities

Generally speaking, one can say that success of a capability in defence, or of a military product, is achieved if one manages to learn it speedily and less of this learning is diffused, while imitators tend to be slow in learning. This is the case with certain capabilities such as command and control, or certain products such as fighter planes or the sophisticated computer software of military systems.

On the other hand, the armed forces or firms become losers if they are slow to learn and if their competitors adopt the new capabilities or equipment in a timely manner taking advantage of their dissemination. Hence the confidentiality that the armed forces apply to the development of their procedures and routines, the protection that firms maintain in relation to knowledge and acquired capabilities and the non-disclosure of information regarding certain parts of the exported equipment (black boxes).

Related to this issue is the problem where search and selection mechanisms are over-accelerated, arising from strong rivalry between nations, leading to arms races which, although it will generate superior capabilities for both parties, will not necessarily bring about greater security, just like a price war between companies could ultimately simply lead to bankruptcy.

6.5 The non-linear nature of the evolutionary process

Finally, one should note that the non-linear nature of the processes of innovation, where successful process or product innovations show a skewed-distribution,⁴⁶ means that only relatively few investments will bring up major profits, while the rest will fail to produce appreciable benefits. Therefore, as previously noted, the upgrade of military capabilities is an expensive business.

46 Scherer, F. M., and D. Harhoff. "Technology policy for a world of skew-distribution outcomes". *Research Policy*, 2000, pp. 559-566.

To conclude, there are important limitations preventing defence from evolving towards new capabilities. This leads us to analyse some practical implications, which we will do in the next section.

7. PRACTICAL IMPLICATIONS

The theory of evolutionary economics places emphasis on the role of knowledge in society's capacity to adapt to context and in the search for efficient solutions. Some ideas are tested and are reliable. Others are tested and are rejected and regenerated with new conjectures which frequently constitute variations of the rejected ideas. The final result of this iterative process is greater knowledge, which contributes towards procuring better and more refined solutions.

The main consequence arising from this is that actions aimed at reinforcing mechanisms that generate variety, selection and replication should be promoted. This is a way of boosting knowledge, the basic pillar for the evolution of capabilities towards greater efficiency. This makes it necessary to have an effective institutional structure. By this we mean one that is capable of generating variety and of efficiently sifting through innovations, accepting and disseminating the good ones and rejecting the bad ones; in other words, hosting an environment favourable to innovation and entrepreneurship. In this sense, we see how some nations have better strategies than others based on the important differences in capabilities we observe in practice.

Variety can be boosted with the support of search and learning activities that materialise in research, development and innovation projects, such as the funding of research centres and private initiatives in these areas. In small projects, where the cost of funding the generation of variety is reduced, a decentralised competition of ideas between firms could be more appropriate. This is more difficult in large-scale projects, where the provision of the operational, technical and industrial knowledge of several nations allows for more focused exploration and the analysis of more alternatives thanks to the resources accumulated in a multinational programme.

For these cases, carrying out this activity in the framework of joint European armed forces and a European defence market could be more advantageous. A European vision, in spite of the existing difficulties hampering its realisation, could clearly favour the procurement of better capabilities and a more efficient defence. Another alternative is to imitate the solutions of other nations and industries, which are clear leaders in defence, by making the appropriate adaptations with the double objective of reducing the efforts involved in the search process and obtaining a better product, an option frequently adopted by the Europeans in relation to US developments.

The selection mechanism requires a special design in order to avoid two errors. The first is the lack of success as a result of the search in barren areas. The second is the

survival of erroneous elections. Mitigating these two problems again involves greater knowledge. Therefore, it is recommendable that decision-makers should personally have the greatest experience and knowledge of the research in question, or they should be assisted by staff with the required expertise or by independent consultants. In this sense, organizations such as programme offices or main contractors should accumulate sufficient technical and operational talent and knowledge, to guide the way to discovering the best solutions.

Lastly, it is important to foster the diffusion of this acquired knowledge so allowing concepts and technologies to spread⁴⁷ within the armed forces, the defence industry and other organizations such as allied armies or civil firms. This diffusion of knowledge ought only to be bounded by the need to prevent certain doctrines or certain technologies from falling into the hands of a potential adversary. Thus the Administration can foster the implementation of a new technology, whose effects spill over the rest of the economy, as is the case of satellite positioning systems and other general purpose technologies.

This promotion could extend to the support of (it is difficult for the Administration to act on its own) activities geared towards coordinating specialised knowledge and favouring the cross fertilization of ideas, with the formation of seminars, or the formation of *joint ventures*. This support is necessary, bearing in mind that a firm has few incentives to disseminate knowledge, and tends rather to hide it or prevent its use via patents.

8. CONCLUSIONS

This brief article has presented an evolutionary vision of defence highlighting the growing complexity of military capabilities –characterised by a more sophisticated organisation, a more advanced doctrine and equipment with ever more functions and features permitting an ever greater protection of society. This evolution is governed by a constant process of change allowing for increases in knowledge and the development of capabilities better adapted towards the solving of military problems. In this framework the new capabilities are the fruit of a co-evolution between knowledge, operational procedures and material means.

As can be observed in practice, the mechanisms of this evolution are capable of achieving significant results, despite the limitations mentioned. Thus, the effectiveness of human proposals, intelligence and future vision ought to be complemented by the

47 See, for example, Geroski, P. A. “Models of technology diffusion”. *Research Policy*, 2000: 603-625.

generation of a series of variations and alternatives of a certain random nature (*ex ante*, without entirely knowing what is the correct thing to do) and an *ex post* selection, permitting the correction of errors committed due to limitations of knowledge and calculation, in order to achieve a better solution in the long term.

This evolution entails processes of learning and discovery, which absorb important economic resources whose profitability is not always guaranteed. This major difficulty accounts for the lengthy and tortuous progress of the armies' military capabilities, a question that is generally under-rated.

Settling institutions and organisational structures capable of better underpinning the development of military capabilities is an indispensable requirement in ensuring that these can protect society efficiently. This requires the creation of a favourable framework and mechanisms for its constant review to confirm that these structures and institutions fulfil their function adequately.

BIBLIOGRAPHY

- Alic, J. A. *Trillions for Military Technology. How the Pentagon Innovates and Why It Costs So Much*. New York: Palgrave MacMillan, 2007.
- David, P. A. "Path Dependence, its critics and the quest for 'historical economics'" in *Evolution and Path Dependence in Economic Ideas: Past and Present*, edited by P. Garrouste and S. Ioannides. England: Edward Elgar Publishing, Cheltenham. 2000.
- Dosi, Giovanni, and Richard Nelson. "An introduction to evolutionary theories in economics". *Evolutionary economics*, 1994: 153-172.
- Downs, A. *Bureaucratic Structure and Decisionmaking*. Memorandum RM-4646-1-PR. Santa Mónica, CA: RAND. 1966.
- Geroski, P. A. "Models of technology diffusion". *Research Policy*, 2000: 603-625.
- Hartley, Keith. *The Economics of Defence Policy: A new perspective*. Routledge, 2011.
- Henderson, R., and K. Clark. "Architectural innovation: the reconfiguration of existing product technologies and the failure of established firms". *Administrative Science Quarterly*, 1990: 9-30.
- Leitenberg, M. "The dynamics of military technology today". *International Social Sciences Journal*, 1973: 336-357.
- Martí, Carlos. *Tecnología de la defensa. Un análisis de la situación española*. Madrid: Instituto Universitario General Gutiérrez Mellado, 2006.

- Martí, Carlos. *Sobre la eficiencia en defensa*. Madrid: Instituto Universitario General Gutiérrez Mellado, 2015.
- Millet, A. R., W. Murray, and K. H. Watman. "The Effectiveness of Military Organisations". *International Security*, 1986: 37-71.
- Nelson, R., and Nelson, K. "Technology, institutions, and innovation systems". *Research Policy*, 2002: 265-272.
- Nelson, Richard. "The role of knowledge in R&D efficiency". *The quarterly journal of economics* (OR), 1982: 453-470.
- Nelson, Richard. "¿What enables rapid economic progress: what are the needed institutions?" *Research Policy*, 2008: I-II.
- Nelson, R. R. and Winter, S. "In search of useful theory of innovation". *Research Policy*, 1977: 36-76, p. 68.
- Nelson, Richard, and Sydney Winter. *An evolutionary theory of economic change*. The Belknap Press, 1982.
- North, Douglas. *Institutions, institutional change and economic performance*. Cambridge University Press, 1990.
- Pavitt, K. Sectoral patterns of technical change: Towards a taxonomy and a theory. *Research Policy*, 13: 343-373. 1984.
- Polanyi, M. *The Tacit Dimension*. University of Chicago Press. 1966.
- Rivkin, J. W. "Imitation of complex strategies". *Management Science*, 2000: 824-844.
- Rosenberg, Nathan. "The direction of technological change: inducement mechanism and focusing devices". *Economic development and cultural change*, 1969: 1-24.
- Rosenberg, Nathan. "Science, Invention and Economic Growth", *The Economic Journal*, 1974: 90-108.
- Schumpeter, J. A. *Capitalism, Socialism and Democracy*. New York: Harper & Row. 1942.
- Simon, H. A. *Rational decision-making in business organizations*. Nobel Memorial Lecture. Stockholm. 1978.
- Scherer, F.M., and D. Harhoff. "Technology policy for a world of skew-distribution outcomes". *Research Policy*, 2000: 559-566.
- Tushman, M., and D. Anderson. "Technological discontinuities and Organizational Environments". *Administrative Science Quarterly*, 1986: 439-465.

Utterback, James M., and William J. Abernathy. "A dynamic model of process and product innovation". *The international journal of management sciences*, 1975: 639-656.

- Submitted: June 1, 2015.

- Accepted: September 4, 2015.
