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Portugal's Changing Defense Industry: Is the Triple Helix Model of Knowledge Society Replacing State Leadership Model?

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Abstract: The defense industry has unique features involving national sovereignty. Despite the characteristics that led to the separation of the military and civil spheres, since the 1990s, the number of dual-use projects has been growing. Taking into account that Portugal is a small European country, this paper analyzes the relationships within the defense industry in order to determine how university–industry–government relationships (the Triple Helix) function in this specific industry. The analysis of 145 projects of the Portuguese Ministry of Defense led to the following conclusions: first, academia was represented in more than 90% of the projects, and 40% of those projects have a dual-use application; second, there is a predominance of knowledge production, dissemination and application, for which the university's institutional sphere is essential and third, the Triple Helix system evolves into a network of relationships that involve projects with both civil and military applications.

Keywords: triple helix; defense industry; university-industry-government; Portugal

1. Introduction

The security and defense of a country are a matter of sovereignty and governments consider the integrity of the defense industry very carefully. This situation introduces features that extend beyond market logic and competitiveness is assessed, more than in any other industry, by criteria based on performance and technological superiority capable of guaranteeing some strategic advantage over other countries. The defense industry is a very specific component of the economy, characterized by the major involvement of public authorities and the search for high technological prowess [1–3].

Technology and innovation are widespread, as products are varied and include fields such as: construction, automobiles, aerospace, textiles and garments, ballistics, electronics, and information and communication technologies that can be used in the defense industry, but also have dual-use purposes, i.e., the development of technologies with military use and the capacity to be incorporated into civil applications. These dual-use projects create a dual economy as, on one hand, it is subject to market rules and, on the other hand, it is monitored by the government [4]. This fuzzy boundary makes it very difficult to analyze the economic spillovers from research and development (R&D) projects. Dowdall [5] claims that the supply chain of the defense industry is under-researched when compared to other supply chains, due to the complexity of the products, the difficulty in accessing data, and the complexity of economic networks.

The high production costs and the concentration of the defense industry increasingly lead countries to prioritize "off the shelf" solutions available in the international market, rather than developing their own military equipment [2,3,6–8]. However, imported technology needs to be adapted in order to be compatible with the defense doctrines, infrastructures and requirements that are specific to the importing country. As a result, the domestic innovation infrastructure must cope with such adaptation processes [7], and this drives the inclusion of non-traditional knowledge-based suppliers, such as universities and high-tech firms [9]—the non-traditional knowledge-based suppliers were named after the Second World War as the scientific and technological knowledge, for military and security purposes, was traditionally generated by the military, government laboratories and defense contractors [9]. Governments do not decide the features of military R&D infrastructures alone, and the defense industry is increasingly dependent on technologies and innovations with civil or dual-use origins [9].

Despite the importance of defense R&D investments, the spillover effects are still unknown as there has been no proper appraisal [5,10].

The particularity of the innovation processes in the defense industry has been analyzed by Sempere [11], who asserts that when a new good is developed in the defense industry, the institutional arrangements that support innovation and the effect of innovation on industrial markets lead to poor performance in terms of product quality, cost and delivery time. The causes of poor performance are [11]: the decisions that are frequently conditioned by non-economic reasons; the uncertainty of defense needs; the weak competition of the defense market; the short production runs, the lack of coordination within military alliances and the unclear impact of spill-overs to the civilian market. Although some policy implications are put forward as a possible remedy, making the market more efficient does not automatically ensure effectiveness, because of the product's complexity, the lack of economies of scale, and the uncertain outcomes that may hinder co-operation among parties in the supply chain, which is dominated by a few main contractors.

The importance of innovation in the defense industry must be addressed from a systemic perspective as a result of the interdependencies between actors, organizations and institutions [12]. The main focus of this innovation system perspective is on interactive learning as the driving force of economic development with consequences at the regional and sectoral levels [13–15].

Following a systemic perspective, the Triple Helix model is based on the hybridization of elements from the university, industry and government that generates new forms of production, transfer and application of knowledge [16–18]. The Triple Helix system provides a fine-grained view of innovation actors, and the relationships among them, accommodating both institutional and individual roles that transcend sectoral and technological boundaries [19].

Innovation in the defense industry is very particular as, in each country, there are companies, military organizations, defense-related government agencies, academic institutions and R&D institutes with specific capabilities that can establish partnerships for the development, production and adaptation of military equipment. Any country can make use of the combined contribution of the Triple Helix system [7].

There are huge differences in R&D expenditure between countries [11]. The defense and security strategies in countries such as the USA, UK, and France, with longer traditions of adapting their industrial capabilities to defense [20–24], are also different from those of small countries like Portugal [25–28]. Because R&D activities are concentrated in a few countries, and there are few studies of innovation activities in small countries, the research question this paper seeks to address is: how is the Portuguese defense industry changing? To answer this question the Triplex Helix framework is going to be used. Firstly, this paper analyzes the outcomes of the Triple Helix model as applied to the defense industry in Portugal, and then depicts the roles the institutional spheres of university, government and industry play in this context. R&D projects in the defense industry are analyzed using data from the Ministry of Defense. Based on those results, a comparison with the defense industries in the USA, UK, France and China (the most studied countries in the literature) is carried out.

The remainder of this paper is structured as follows. The literature review encompasses the Triple Helix model, the systems of innovation and the defense industry, in general, and in Portugal, in particular. Then, the methodology section outlines the data collection methods used. The results section, presenting the results, is followed by the discussion section. The conclusions are presented in the final section.

2. Literature Review

2.1. The Triple Helix Model

The Triple Helix was introduced in the 1990s [16–18] to describe the innovation model based on the dynamic relationship between university, industry and government institutions. It emerged from studying the work of the Massachusetts Institute of Technology and its relationship with the high-tech industries surrounding it. They worked in accordance with the Triple Helix, although the terminology and the theory were not used [29].

The relationships between university, industry and government led to the Triple Helix approach as an innovation spiral model that incorporates the various reciprocal relationships at different stages of knowledge creation and dissemination, contributing to economic development. This can be very important as entrepreneurial universities with strong corporate links can generate dynamic socioeconomic environments and play an important role in the globalization process of less-favored regions and industries [30].

The model reflects the shift from an industrial society, in which the relationships established by the industry–government dyad prevail, into a knowledge society, characterized by the university–industry–government triadic relationship, where institutions develop Triple Helix intersections while preserving their identity and specific roles [19,29,31].

The concept suggests that, in the knowledge society, innovation and economic development provide a greater role for the university. There is a hybridization of elements of university, industry and government institutions to create new institutional and social formats for knowledge production, transfer and application [19].

Unlike Innovation Systems [12,32], which focus on companies and attribute predominance to the government, the Triple Helix Model emphasizes the university as an essential institution, a source of entrepreneurship and technology, introducing a different critical analysis associated with the scientific process through review mechanisms. It is further recognized as having a pivotal role in crossing the functions established between the parties involved in the triad for the creation of new formats for knowledge production, transfer and application [19,29,31].

Knowledge becomes a crucial resource and assumes the main role in advanced economies, where it is the foundation for the emergence of new industries and is directly associated with a country's economic performance [33–38].

The importance of the Triple Helix model is well expressed in the support of sustainable innovation among firms, as the more information they receive from the participants of the Triple Helix system, the more sustainable they are [39]. The importance of transnational innovation ecosystems is addressed by Cai et al. [40], who claim that transdisciplinarity among players is important to achieve transnational university–industry co-innovation networks. This highlights the importance of not only open innovation in cooperative activities among Triple Helix players but also among transnational players.

2.2. Innovation Systems and the Defense Industry

The literature on innovation systems has grown over time and the importance of knowledge flows between parties has given rise to models such as Open Innovation [41,42] and the expansion of the Triple Helix to a Quadruple Helix [43], comprising the public, and a Quintuple Helix [44], adding the environment.

Different frameworks have been used to characterize different dimensions, boundaries and units of analysis that involve mainly national [12], regional [13–15,45], sectoral [46] and technological [47,48] innovation systems. According to Rakas and Hain [49], most studies adopt a historical perspective that leads to heterogeneity of research perspectives and understandings. However, studies analyzing the defense innovation system are not abundant. For example, WWII significantly changed the United States' innovation model as the State was absent from science and engineering academic research was not deemed as a responsibility of the federal government, and almost all financing came from private institutions [50] and with the development of the atomic bomb, the American government invested in research areas with universities to keep abreast of technological knowledge generated by universities and to achieve technological superiority, by broadening scientific networks, as the industrial market competition was clearly not enough to address military superiority.

This disruptive innovation policy, referred to as *military–industrial–academic complex* [51], led to the organization and development of a Triple Helix-based perspective, composed of the military, governmental laboratories and defense suppliers [9], which led to a knowledge production model progressively more dependent upon dual-use and civilian-based technologies leading to the emergence of a more open defense innovation system that includes civilian suppliers of knowledge among high technology small firms and universities [9,52,53].

The literature on innovation has given prominence to the role played by the defense in developed and powerful countries [5,9–11,24,52–56].

Defense-related R&D is pursued for more than just economic reasons. It is at the heart of the industrial policy in countries such as the UK, the USA and France, where resources are used to influence the speed and direction of innovation in the economy, because defense R&D is the largest single component of the government R&D budget [57]. Despite the technological dominance of the USA and Europe, in the last few decades, China is closing the gap with the West [58,59].

The classic approach to technology transfer in the defense industry in many countries involves the promotion of spin-offs, where military technologies developed in government-led projects are transferred to society. Subsequently, defense innovation systems evolved into a spin-in logic, where the main concern is to expand the defense industrial and technological base [20] and prioritize activities and dual-use research involving the convergence of research activities and the integration of civilian and military innovation structures [20,22]. This transition to a predominantly market-driven system has not occurred in all countries.

In the UK, there has been a profound change in the way skills are distributed between the public and private sectors, based on a liberal perspective, in which the boundaries between the new entities and the system are shaped by transactional criteria [20,23,60]. The UK represents a model where the government is ready to entrust almost everything except front-line operations to the private sector [20].

The inconsistencies and contradictions of this perspective are mitigated by the adoption of measures inspired by the knowledge economy, giving rise to a hybrid structure characterized by numerous knowledge networks and platforms, involving public and private actors [20]. For a knowledge-based innovation system to thrive, it is mandatory to foster local experience-based, context-bound knowledge in order to generate trust-based patterns of cooperation that lead to the accumulation of competencies throughout the system [61]. According to Rakas and Hain [49], what matters is the process of knowledge integration that should evolve from a Fragmented Specialization (Low diversity–Low coherence of knowledge structures) to a Coherent Diversification (High diversity–High coherence of knowledge structures).

In the USA, the security and defense strategy has been built around maintaining a substantial technological superiority, so that government R&D investment is seen not only as a pillar to support its industrial base [11,21], but also as a driving force for maintaining technological superiority. After the Cold War, technical tasks were increasingly transferred to the private sector, where institutions with competencies in integrative systems became more relevant [62]. Even after the fall of the Berlin Wall and the collapse of the Soviet bloc, the American innovation system demonstrated adaptability to keep defense R&D at the core of the system. The USA managed to break up the military and civilian spheres by increasing the cooperation between government, industry and universities to ensure the diffusion of innovation to and from the military sphere [22,23].

There is an explicit involvement of the university and industry in the defense innovation system/industry [23,63–65], which is underpinned by the following facts: (i) the US Department of Defense finances more than half the fundamental research outlays of universities; (ii) more than three-quarters of the budget of the Defense Advanced Research Projects—responsible for radical innovations—is devoted to industry; (iii) the partnerships promoted by the Ministry of Defense with thousands of innovative small and medium-sized enterprises (SMEs); and (iv) funding shifted from universities to industry (especially, established vendors) and funds tied to go/no-go reviews linked to pre-defined deliverables.

With this strategy the US government no longer plays the traditional role of client and becomes a partner [22], introducing dynamism into the system, expressed in the capacity to transfer knowledge and innovation among all the main players of the system [12]. Thus, military programs assume a pivotal position in the knowledge economy of the USA [22].

In France, this type of relationship is less balanced, since the government retains the key role in financing and executing defense innovation projects, hindering the proactive role research could play in technology transfer. The ministry of defense leads the dual-use policy through the *Délégation Générale pour l'Armement* (DGA), which serves as the interface between civil actors in the field of research and innovation and military authorities. In contrast to the American system, the French R&D and defense systems remain separate and there is no complementarity between knowledge and innovation or between civil and military funding [22].

With the rationalization of the DGA's activities, the French government reoriented investments from upstream research to the production phase so that capabilities shifted to applied research. However, the loss of technological capabilities was partially offset by the development of collaborative networks and the transfer of knowledge among companies in various technological fields [66]. As a result of this strategy, the DGA has shifted its traditional role of System Integrator to a more market-oriented position tuned to the interests of large corporations, which not only have been privatized, but have also taken on an integrative role. In turn, the new objective of the DGA is to subcontract and monitor collaborative networks [24,66].

Although the DGA launched some exploratory projects with universities and SMEs, which created new networks and established relationships between various public and private organizations, this initiative was not enough to reposition the DGA in the defense innovation system [24]. The interaction between the defense ministry and SMEs is less intense than in the UK and the USA [23].

Nevertheless, the French defense innovation system became more open, and integration and control capabilities have become critical [24]. On the other hand, defense companies have accelerated the exchange of internal and external knowledge and large companies have benefited from technology transfer and gained greater autonomy, reinforcing their role as system integrators. As a result, industry has taken a more central role [24,56].

In China, the techno-nationalist model of imitating technology emphasizes the role of the state and downplays market forces when it comes to developing local arms industries [67]. This is being challenged with the gradual but accelerating shift from imitation to indigenous innovation, in the pursuit of closing the gap with the West [58–68].

To sustain its radical swift in climbing the innovation ladder, China is opening its access to capital markets, enhancing the role of defense conglomerates, improving linkages with global innovation and technology networks, and fostering civil–military integration activities with growing attention being paid to closer coordination and integration between universities and research institutes and industrial enterprises [59,68,69].

Although tuned with the major trends of western innovation models, significant differences make parallelisms with China challenging as while its civilian economy is tightly integrated with the global economy, western allies have excluded the Chinese defense industry. Moreover, overall, defense industries do not have the advanced systems integration capabilities needed to link highly complex systems-of-systems [59,67,69].

When comparing the different defense systems, two major trends can be identified in the interaction between university, industry and government [23]: (i) knowledge networks dedicated exclusively to the production of military equipment have been dismantled, except in the USA; (ii) the growing role of industry and academia in the field of innovation entails new partnerships between public and private actors. The interactions between university, government and industry are a main source of innovation, and maintaining dynamism in the defense industry requires the creation of an interactive network of the traditional actors responsible for military equipment and the new actors in industry [23,54].

Since innovation is not a linear process, the knowledge needed to pursue complex programs is dispersed between research (universities), firms (industry) and end-users (government) with specific responsibilities for each area. Academia develops research and knowledge concerning the phenomena and facts. Industry, through prime contractors, increases the capabilities to integrate complex systems, thereby embracing a central role in knowledge networks related to the industrial production of defense goods. The state, as the sole user of military equipment, seeks to acquire and retain the critical capabilities, information and knowledge to make the best technological decisions and behave like a smart buyer [23].

2.3. The Innovation System and the Portuguese Defense Industry

In the second half of the 1950s, the defense industry was at the forefront in Portugal. As a founding member of NATO in 1949, the country was included in this organization's scientific and technological programs, and so the national industry evolved quickly, responding to requests from allies, and becoming involved in state-of-the-art technology projects [28,70].

In the 1970s, the onset of conflicts in the Portuguese territories in Africa caused a reversal in priorities. Resources were put into projects oriented to this conflict and the technologically advanced resources developed in partnership with the allies were abandoned—as they would have diverted resources into technologies that were deemed a low priority—in order to meet the requirements of counter-guerrilla operations [70,71]. Until the end of the conflict in 1974, to reduce dependence on outside sources for the equipment used in the wars in Africa, the national defense industry increased its production capacity but focused less on quality [70].

Between 1977 and 1997, private industry was prevented from taking part in R&D, trials, testing, maintenance or production of equipment intended exclusively for military applications by law [71], and so R&D activities for the defense industry only started in a systematic manner in the late 1990s [28].

The restructuring of the Portuguese defense industry and its privatization started in the second half of the 1990s, although a residual part of this industry was kept under state control [71].

Until the beginning of the 21st century, the sphere of government institutions exercised a hegemonic predominance, with few national private equity companies involved in a small number of defense R&D projects [28]. Between 1996 and 2002, there were hardly any consortia between academia, companies and the Armed Forces in the pursuit of defense-related R&D projects. The government had primary responsibility for the technological development of the sector and for the involvement of academia and industry (mostly public entities) in addressing military needs.

Barros [25–27] identified serious performance problems in the Portuguese defense industry and recommended the introduction of innovation to change its course.

The government decided to incorporate knowledge, technology and innovation as the main vectors of the National Defense Strategic Concept [72]. The defense R&D strategy identified the need to promote innovation and to exploit collaboration between the National Scientific and Technological

System (university), the Defense Technological and Industrial Base (DTIB) (industry) and the Ministry of Defense (government) [73]. It is clear that an implicit Triple Helix framework was present in the strategy for the defense industry.

In line with the Development Strategy of the DTIB, which supported the promotion of public policies that stimulate networking between research centers, universities and companies [74], the DTIB has been expanding [75–77] and currently consists of 385 entities [78].

Although the Hydrographic Institute develops innovation activities related to marine sciences and technology [79], academic institutions coordinate and supervise most of the R&D activities of the armed forces, as the promotion of innovation activities in the Portuguese Armed Forces is primarily located in the Military University Institute's research center and its autonomous units, the research centers of higher education institutions (HEIs) of each of the branches of the armed forces [80]. A recent study has confirmed that the Portuguese industry consists mainly of micro, small and medium-sized dual-use companies [81].

In most countries, companies that are system integrators play an increasing role in the defense industry [24] and private sources fund the acquisition of industrial capacities and competencies, especially in countries with reduced defense budgets.

This context suggests the relevance of using the Triple Helix to investigate the influence of different actors (university–industry–government) in the defense innovation system of a small country like Portugal, with a substantially lower defense budget than that of countries with the highest military investments and a technological and industrial defense base consisting essentially of micro, small and medium-sized enterprises.

3. Methodology

Information concerning defense industry projects was obtained from the Ministry of Defense of Portugal. In some cases where the data provided were insufficient, they were supplemented with information from the partners and financing entities of the projects. The Ministry of Defense and its Branches—Navy, Army and Air Force—were asked to indicate the projects involving external entities, from 2010 to 2017—which was the only data we had available—specifying the following elements:

- title (name);
- description (short summary);
- period (starting and ending year);
- entities involved (name);
- Finance sources.

The research paradigm adopted in the present study is realism, which epistemologically values the generation of knowledge [82]. Realists consider that only observable phenomena provide credible data, and focus on explaining phenomena within certain contexts.

Realism shows how the empirical findings of a given research project align with theories. A research method with an analytical quantitative-based approach was used, which allows an insight more related to the practical applicability of the literature and leads to a greater understanding of the reality of the projects according to the Triple Helix model. This allows an interpretative approach to reality, using a convenience sample, given that it was only possible to evaluate a database containing projects from 2010 to 2017.

As in previous studies, the institutional actors have been placed into categories according to one of the following classifications, based on the Triple Helix model: "university", "industry" or "government" [83–85]. This allocation was carried out by classifying knowledge institutions (universities, faculties, research institutes, technological centers, military universities and academies) as "university". Although this could be argued, research institutions and technological centers work very closely with universities and are normally supported by the budget of the ministry of science and higher education. Civil organizations (chambers of commerce, industrial and environmental associations), general directorates, agencies, laboratories, national institutes and other institutions dependent on municipalities, regions, ministries or transnational organizations (NATO and the UN) as "government". This decision was based on the fact that those institutions participate in defense-related projects through funding from the government or transnational organizations. Finally, companies were categorized as "industry".

For each project, the information was converted into binary variables according to the positive (1) or negative (0) identification from each of the institutional spheres, namely university (U), industry (I) or government (G). The combinations UI, UG, IG and UIG were used when the project involved more than one institutional sphere.

The data were systematized in an Excel database, listing the designation, starting date, scope of funding and origin of each. The number of projects in each institutional area was identified (university, industry, government), as well as any combinations.

The classification of project scope followed the Ministry of Defense's criterion that classifies national and international R&D cooperation activities as primarily defense or primarily dual-use according to the coordinating entities and/or project funding bodies [71]. The projects were classified as follows:

- International defense projects, involving the European Defense Agency (EDA) and the North Atlantic Treaty Organization (NATO);
- National defense projects, The Ministry of Defense (MDN) and respective branches (Navy, Army and Air Force);
- International dual-use projects, involving the European Economic Area (EEA) Grants, projects involving European funds managed directly by the European Union, trans-border projects (Portugal–Spain) and other projects with a foreign origin;
- National dual-use projects, involving the Foundation for Science and Technology—*Fundação para a Ciência e a Tecnologia*, which is a Portuguese public agency, within the Ministry for Science, Technology and Higher Education that evaluates and funds scientific research activities –, European funds managed locally and other projects with national origin.

4. Results

The database comprised of 145 projects in which there were identified and categorized 620 different entities—224 as university, 165 as industry and 231 as government. The high number of entities is explained by the involvement in international projects that comprised dozens of participants. From the 620 entities, 166 were Portuguese, 377 from other European Union (EU) countries, 62 from non-EU countries and 15 belonging to international/multinational bodies (institutions with members from several countries).

The different scopes of the projects are presented in Table 1. As such, more than 40% of the projects have a dual-use purpose, i.e., have a civilian application as well as a military one.

Table 1. Project scope.

Total Number of Projects	Scope			
	International Defense Projects	National Defense Projects	International Dual-Use Projects	National Dual-Use Projects
145	23	62	33	27

As shown in Table 2, University is the institutional sphere with the largest number (133) of projects (92%), significantly ahead of the government with 93 (64%) and industry with 82 (57%).

Table 2. Triple Helix relations in the Portuguese defense industry.

	Total Amount	University	Industry	Government	UI	UG	IG	UIG
Number	145	133	82	93	73	81	62	53
Percentage	100%	92%	57%	64%	50%	56%	43%	37%

The predominant role of the university is in line with the Triple Helix theory, since the development of economic potential and innovation in knowledge societies is strongly dependent on this institution for knowledge production, transfer and application [19,86]. More than 40% of the projects involve at least two institutions (UI, UG, GI), and 37% involve the three institutional spheres (UIG). These results are in line with the Triple Helix concept that advocates the evolution towards a knowledge society with increasing influence of university–industry–government relations [19], indicating that, within the Portuguese defense innovation system, this type of relationship occurs systematically.

After assessing the Triple Helix relationships in the Portuguese defense innovation system, it is important to explore the involvement of each institutional sphere.

4.1. University

Table 3 shows the total number of projects that comprise the institutional sphere of the University, identifying the number of projects involving Portuguese entities. In total, 89 (75.4%) of the 118 projects of the Portuguese HEIs were carried out by Portuguese military academies (Naval School, Military Academy and the Air Force). Despite this predominance, there are only eight projects in which only Portuguese military academies participate. This means that most of the projects involve both civil and military institutions classified as "university".

Table 3 also shows the projects classified as University detailing information concerning the Portuguese military academies, leadership roles and scope of the projects.

Table 3. Projects with participation and leadership roles of national entities classified as University.

Entities Involved	Total Number of Projects	Scope			
		International Defense Projects	National Defense Projects	International Dual-Use Projects	National Dual-Use Projects
Portuguese entities classified as "university"	118	19 (4)	54 (38)	19 (3)	26 (10)
Portuguese military academies	89	10 (-)	48 (35)	13 (-)	18 (-)

Note: Leadership roles are given in parentheses; Military academies have university level degrees accredited, and recognized by the Portuguese Ministry of Science, Technology and Higher Education.

4.2. Industry

Of the 145 projects analyzed, 60 involve at least one of the 48 Portuguese companies identified in the database (including the subsidiaries and national representatives of multinational companies). Only 11 projects have more than one national company among their partners, and only six companies participate in three or more projects.

Table 4 identifies these companies indicating the key sector in which they are positioned, the total number of projects, the scope in which they were developed and the number of projects in which they were leaders, that is, in which they coordinated the consortium.

Table 4. Projects with participation and leadership roles involving Portuguese companies that participate in three or more projects.

Name	Key Sector	Total Number of Projects	Scope			
			International Defense Projects	National Defense Projects	International Dual-Use Projects	National Dual-Use Projects
Alpha	Unmanned aerial vehicles, Unmanned underwater vehicles, Unmanned ground vehicles	11	6 (2)	1 (-)	2 (2)	2 (2)
Beta	Aerospace industry	7	- (-)	4 (1)	- (-)	3 (2)
Gamma	Aerospace industry	4	- (-)	- (-)	4 (2)	- (-)
Delta	Construction and Engineering	3	1 (1)	- (-)	2 (2)	- (-)
Epsilon	Textile	3	2 (-)	1 (-)	- (-)	- (-)
Zeta	Communications and IS	3	1 (-)	2 (1)	- (-)	- (-)

Note: Leadership roles are given in parentheses; for confidentiality reasons, the real names of the firms are not released; the names of the firms are given in the Appendix A.

4.3. Government

Of the 93 projects identified as having government involvement, 74 involve Portuguese institutions, of which 61 depend on the Portuguese Ministry of Defense. Table 5 shows the government entities that participate in three or more projects.

Table 5. Projects involving Portuguese entities that belong to the government sphere.

Name	Total Number of Projects	Scope			
		International Defense Projects	National Defense Projects	International Dual-Use Projects	National Dual-Use Projects
Instituto Hidrográfico [Hydrographic Institute]	30	- (-)	4 (3)	18 (1)	8 (1)
Centro de Psicologia Aplicada do Exército [Army Center for Applied Psychology]	6	- (-)	6 (1)	- (-)	- (-)
Instituto Português do Mar e da Atmosfera, (IPMA) [Portuguese Institute of the Sea and the Atmosphere]	6	- (-)	- (-)	3 (-)	3 (-)
Laboratório de Bromatologia e Defesa Biológica do Exército [Laboratory of Bromatology and Biological Defense of the Army]	6	2 (-)	3 (1)	1 (-)	- (-)
Escola das Armas [School of Arms]	5	1 (-)	4 (3)	- (-)	- (-)
Centro de Informação Geoespacial do Exército [Army Geospatial Information Center]	3	- (-)	3 (1)	- (-)	- (-)
Operational Units of the Armed Forces *	8	- (-)	8 (7)	- (-)	- (-)

Note: Leadership roles are given in parentheses; * these projects were carried out by operational military units and not by formal institutions.

5. Discussion

The resources required for the development of the capacity of the Portuguese defense industry [73] means that, in most of the projects identified, there is a collaboration between at least between two of the institutional spheres (university-industry-government), and that over a third of the projects involve the three institutional spheres (university-industry-government). New scientific and technological challenges are more intricate and cover various fields of knowledge.

The results also indicate that dyadic industry-government relationships, characteristic of industrial society, are the least common in the defense system. The university takes a leading role, as the institutional sphere involved in most projects (over 90%), and dyadic relationships including academia (university-government and university-industry) are the most common, 56% and 50%, respectively.

These results show the key role of knowledge in the Portuguese defense industry, where the predominance of academia—perhaps overemphasized by the presence of both universities and military academies—indicates that government and industry can access and share knowledge through it, thereby confirming that the Portuguese defense industry acts as a system in transition to a knowledge society.

Although academia is the most important institutional sphere in the Portuguese defense innovation system, the specificity of national defense as an institutional entity is relevant. As innovation and R&D activities in the Armed Forces are concentrated in the research centers of HEIs, military academies are involved in more projects with entities classified as "university". Another specificity is the joint participation of military and civil entities in projects, indicating a demand for civil knowledge among the institutions of the Portuguese Defense industry, in order to carry out R&D activities of interest to the Armed Forces. Another important feature is that, although the institutional sphere "university" has the capacity to lead both defense and dual-use national and international projects, Portuguese military academies only co-ordinate national defense projects.

Industry is increasingly involved in research projects of the defense industry, but is restricted to a very small number of firms that focus on technologically related areas such as unmanned vehicles, aerospace and information and communications systems. Outside this core, five firms from the textile industry were among the 48 Portuguese companies identified in this study, and they participate in six projects.

Although it is the smallest institutional sphere, industry leads national and international defense and dual-use projects, as is the case of the CAMELOT Project, which involves HEIs, industry and government entities from more than a dozen countries [87].

Evidence of industrial competitiveness and competence can be seen by the fact that Portuguese companies lead: (i) the consortia selected by EDA (from many candidates that belong to more than a dozen countries) for the first "Turtle" pilot project to explore the use of European funds in dual-use applications [88,89]; and (ii) the first "SPIDER" project in the field of defense research, funded directly by the European Union [90–92].

Despite the small size of the Portuguese defense industry, companies in specific sectors have the capacity to coordinate complex national and even international projects involving the university, industry and government. This means that the Portuguese defense innovation system follows the trend of other countries where industry gradually takes on a more prominent role as a system integrator.

Government involvement is characterized by the fact that, with the exception of IPMA, all the entities that participate in more than two projects belong to the sphere of influence of the Ministry of Defense (see Table 4). The data indicate that, excluding the Hydrographic Institute, the participation of these institutions is centered on projects classified as National Defense, where the Operational Units and the School of Arms lead the vast majority of the projects in which they participate, promoting relations with entities outside the Ministry of Defense to respond to operational matters of military interest. Concerning the interaction between the defense industry and the rest of the scientific and technological system, the military is more interested in the participation of civil entities in their projects than the other way around.

Unlike the USA, where military programs occupy a key position in the knowledge economy and research in military laboratories is considered essential, representing a competitive element with private research [21–23], in Portugal, with the exception of the Hydrographic Institute, this characteristic is absent from the national innovation system of defense. The Hydrographic Institute is unique because: (i) it is the only agency that depends on the Ministry of Defense recognized as a state laboratory; (ii) it enjoys administrative and financial autonomy; (iii) it is the main national governmental institution with activities related to marine sciences and techniques [77] developing R&D activities, in partnership with other national and foreign institutions, to be applied in the military field and to contribute to the development of the country in the areas of science and defense of the marine environment [93].

The government's contribution to the defense innovation system is inwardly oriented, participating in civil and international knowledge networks. This feature manifests itself in the dual role of government as the regulatory party and the main customer [2] and is reflected in the fact that—in the Portuguese cooperative context—the Ministry of Defense is the only national entity funding purely military projects, establishing a close link with other fund management institutions in "dual-use" projects [71]. Hence, the Ministry of Defense acts as a connection, customer, promoter and facilitator of relations between the armed forces, civil society and international fora [73].

In 2016, the first contract for unmanned aerial systems performed by a European civilian agency was awarded, in 2016, to a Portuguese Air Force led consortium and, in 2017, the largest of this kind of contracts, to a consortium led by a Portuguese firm, in direct competition with the largest companies in the sector, such as Airbus and Safran [94–96]. The award of such a contract to the consortium led by the Air Force, in partnership with two private Portuguese companies (also involved in projects identified in this study) allowed this military institution to transfer a technology it had begun to develop in the previous decade in partnership with academia and industry [97,98]. This shows that the Air Force has reached a level of technological maturity that enables them to lead an industry-based project. This is an example of the development described by Dzisah and Etzkowitz [99], who consider that the Triple Helix enables economic development based on endogenous capacities, mobilizing local resources and capabilities.

Commercial contracts granted to a consortium led by the military, which is a function usually associated with industry, are an example of how the Triple Helix leads to new organizational formats, in which actors, apart from taking on their institutional role, may also play the role of another [19,29,31]. The projects analyzed indicate that the participation of the Ministry of Defense is not restricted to the role of end-user, and partnerships with industry and academia support the development and production of specific capacities in the medium and long term.

This development is relevant as unmanned aerial systems, with increased demand in countries around world, play key roles for military and civilian purposes and require critical system integration capabilities and an enhanced ability to allocate resources [52]. This has serious practical implications, which is supported in the literature that emphasizes [30]: the importance of strong university–corporate links to reduce the gap with disadvantaged regions through globalization; the role of government; and the participation in national and international knowledge networks.

Although Portugal also experienced a transition following the major trends identified by Mérindol [23], where university, industry and government collaborate in both military and dual-use partnerships, the Portuguese system has characteristics from those of the UK, USA, France and China. The novelty of a triple helix approach in the Portuguese defense industry is that it presents a compelling rebuttal to the causes of the poor performance of the innovation processes in the defense industry identified by Sempere [11], as the dual-use nature of the Portuguese system and its integration in international knowledge networks address the questions of: (a) decisions being frequently conditioned by non-economic reasons; (b) the uncertainty of defense needs; (c) the weak competition of the defense market; (d) the short production runs; (e) the lack of coordination within military alliances; and (f) the unclear impact of spill-overs to the civilian market.

Portugal's position is far from the liberal perspective of the UK. The government does not outsource many of the value-added business activities to the private sector, retaining skills in the Armed Forces. The Portuguese government's reduced investment in defense-related R&D activities also separates Portugal from the American model, which is based on substantial technological superiority and strong support from the industrial base. Moreover, the lack of scale of most Portuguese firms hinders the development of breakthrough technologies that could lead to a worldwide technology-based strategy. Although the government has a key role in funding defense innovation projects, Portugal is also distant from the French model, since it is the university and industry, instead of the government, that take the lead in most of these types of projects. Finally, Portugal diverges from China's statist perspective, as the Portuguese defense industry is closely linked to the civilian but also military knowledge networks of western allies.

6. Conclusions

This paper focuses on R&D projects in the Portuguese defense industry, in order to identify the collaborative relationships between the institutional spheres of university–industry–government, and, at the same time, to assess how and why the Portuguese defense industry is changing. For that, the involvement of the different institutional spheres in the development of projects with civil and military applications was analyzed.

The results indicate that, despite the specific constraints associated with the defense industry, more than a third of the projects rely on the joint participation of the three spheres (university–industry–government) and about 40% are dual-use projects, which makes explicit the convergence between the military and civil spheres. This clearly indicates how the Portuguese military industry has evolved over time from its closed economy, State-based approach.

Although the 36% of university–industry–government projects is a clear indication of the dynamics the industry is going through, there is plenty of room for more joint participation of the three spheres. With these data one can argument that the Portuguese defense system is far from the dyadic industry–government collaboration model, which is a typical characteristic of industrial societies. It has evolved into a model based on the relationships between academia, industry and government, which is closer to the knowledge-based model of developed countries, with the following specificities:

- University—military/civil overlap, where military knowledge institutions are actively seeking collaboration with civilian counterparts; a reduced influence of the military academies beyond the national scope of defense, which indicates an absence of vocation to lead networks of knowledge with civil objectives and a lack of skills for the coordination of complex international projects.
- Industry—not specific to defense, acting simultaneously in the civil market. It encompasses a very small group of companies that are often involved in defense-related projects that are mostly concentrated in a nucleus of technologically related areas, have system integration capabilities and are internationally competitive.
- Government—constituted, at its core, by institutions under the Ministry of Defense, is geared to responding to internal needs, marginally participating in civil international knowledge networks.

Although it has been possible to identify some hybridization, as some institutions assume the role of the others, academia plays the role of knowledge production and diffusion, which is transferred to the economy by the industry, whereas the government seeks to coordinate the funding of the system. Despite the specificities, there are interactions between the university–industry–government institutional spheres and the R&D projects are important, also at the international level.

It is important to refer that national projects play an important role among Portuguese universities and military equivalents and SMEs play an important role in international projects.

The Portuguese defense industry is leaving behind a typical statist perspective led and controlled by the State, as there are examples of local-experience-based, context-bound knowledge sharing among actors, linking scientific, academic and industrial actors and the accumulation of path-dependent development of competencies that spark competitiveness among all the actors involved. However, the main challenge is to overcome the fragile institutional order imposed by the power of the State and the lack of scale of small firms that compose the industrial sector. Portugal, a small country that was far from the technological frontier of the defense industry, has been able to lead innovation projects in very specific technological areas, and could be a model for other countries. The technological capacity achieved is the result of the involvement of knowledge institutions, companies and government, because only in this way is it possible to mobilize limited resources, to foster, in the short- and medium-term, endogenous competences that capture scattered knowledge to meet specific military needs, as well as to contribute to a development model that stimulates national competitiveness through innovation. Far from being a closed system, the Portuguese defense industry is integrated into national and international networks of creation, diffusion, transfer and application of knowledge, which are developed around an intense collaboration among institutional actors (university, industry and government), in the pursuit of projects with military and civilian applications, and which mobilize civil and defense financial resources of national and international scope.

The results obtained represent a valuable contribution to the existing literature regarding the influence of the Triple Helix on the changing nature of the defense industry. As pointed out, although there is extensive literature regarding explicit involvement of university, industry and government in innovation, there are still very few contributions with examples and practical applications in the field of defense. This paper covers part of this gap with a practical application of the Triple Helix model in a small country. Thus, the analysis carried out shows that even with a narrow triple helix ecosystem comprised of university, industry and government, integrated into national and international knowledge networks it is possible to gain and share significant, technological competencies. This can have relevant contributions to practice as the application of the triple helix model to defense systems can present small or less-favored countries brand new opportunities to reach new socioeconomic development paths. For that, it is mandatory: (a) to abandon a statist perspective, in which the State is the sole user of military equipment, and to accelerate the indigenous innovation capabilities; (b) to be involved in civil-military integration activities; and (c) to embrace locally integrated technologies tightly integrated with global economic networks.

This paper has two main limitations. Firstly, it is based on "counting" the various defense-related projects in which university, industry and government institutions participated, disregarding their monetary value or their technological complexity. Another limitation of this study arises from the absence of databases that could support a more profound examination of this topic.

Future studies could focus on case studies that analyze the participation of specific EU-Cyber academia or The Maritime Unmanned Anti-Submarine system in which Portuguese players play an important role in the development of dual-role projects with important consequences for the knowledge society.

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Appendix A

The Portuguese companies that participate in three or more projects are: A. Silva Matos; Critical Software; DEIMOS Engineering; Damel; GMVIS-Skysoft; Tekever.

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