

Article

Funding and Collaboration in Industrial Doctorates: Insights for the Spanish Model

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Abstract

Industrial doctorates are increasingly seen as a means of linking doctoral education with industrial needs while promoting knowledge exchange between universities and companies. In Spain, this role is formalized through the “Mención Industrial” (industrial doctorate distinction), which provides a framework for collaboration between both sectors. Despite growing interest, its implementation remains limited compared with more established European programmes. This paper presents a comparative conceptual analysis of the Spanish industrial doctorate model, using selected European systems as reference cases to identify opportunities for strengthening university–industry collaboration. The analysis is developed from three complementary perspectives. First, it explores the characteristics that distinguish industrial doctorates from traditional academic PhDs, including supervision, training environment, and expected outcomes. Second, it compares the Spanish model with programmes in France, Denmark, and the United Kingdom. Third, it examines the funding structures that support these initiatives and their influence on university–industry collaboration. The comparison indicates that the effectiveness of industrial doctorate programmes depends not only on institutional design but also on how resources and responsibilities are distributed. In Spain, public support is directed primarily towards the industrial partner, while the university often plays a secondary funding role despite its central contribution to doctoral training. In contrast, other European models provide more balanced funding arrangements. Based on this comparison, a dual-funding approach is proposed in this paper in which both the company and the university receive explicit support. This adjustment aims to improve the alignment between responsibilities and resources, strengthening industrial doctorate programmes.

Keywords: university–industry collaboration; doctoral education; innovation ecosystems



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1. Introduction

1.1. PhD Industrial Training and Training Pathways

University–industry collaboration is not a recent trend. Since the 1950s, governments, universities, and companies have increasingly sought mechanisms to facilitate knowledge transfer, technological innovation, and industrial training. Seminal contributions, such as the Triple Helix model, emphasize the importance of interactions among universities, industry, and government as a key driver of innovation ecosystems and economic development [1]. Hence, industrial doctorate programmes have emerged as a practical instrument to strengthen these relationships by combining advanced research training with industrial engagement.

Industrial doctoral training has been receiving more attention in recent years, mainly because universities and companies are under pressure to work more closely together. This is especially visible in engineering, as doctoral research is increasingly expected to go beyond purely academic contributions and connect with real technological and industrial challenges. This shift can be seen in areas such as Industry 4.0, where doctoral work is already moving toward more applied and interdisciplinary topics [2], and also in broader efforts to better prepare graduates for professional environments outside academia [3].

This link between doctoral training and professional practice is also reflected in broader work on engineering education. For instance, S. Nilson points out that employability in engineering depends not only on technical knowledge but also on a broader set of transferable skills [4]. Similarly, F. Tomassi et al. discuss how the emergence of Industry 4.0 is reshaping the type of competences expected from graduates [5]. At a more practical level, S. Vicente et al. show that exposure to industrial environments, such as internships, can influence how engineering students perceive their readiness for their first job [6]. Earlier work by C. Sansom et al. also shows how closer collaboration between universities and industry can help address specific skill needs in precision engineering [7]. Taken together, these developments suggest that doctoral training in engineering increasingly requires closer interaction with industry, where advanced research and innovation can be developed simultaneously. Industrial doctorates have emerged as one mechanism to support this integration.

In Spain, this type of collaboration is formally regulated by Real Decreto 99/2011, which governs doctoral studies and provides the possibility of obtaining the distinction called “Mención Industrial” [8]. In simple terms, this distinction recognizes doctoral work carried out in collaboration with a company, usually involving joint supervision and a period of activity in an industrial setting. The idea itself is not new, and earlier work has already pointed out both its potential and some of the practical challenges associated with its implementation [9]. In Spain, although supervisors are commonly university academics, Spanish regulations also allow suitably qualified non-academic researchers to participate in doctoral supervision. However, an industrial mentor is mandatory to obtain “Mención Industrial”. To precisely clarify the differences between a traditional academic PhD and the industrial PhD pathway, Table 1 presents a side-by-side comparison in the Spanish context, including who conducts the recruitment and the expected progression of technology readiness level (TRL), which is a standardized scale used to estimate the maturity of a technology during its development phase. Funding sources, the type of supervision and training, and career prospects for graduates are also compared in this table.

Table 1. Comparison between academic and industrial PhD training pathways in Spain, illustrating key differences in research environment, supervision structure, training activities, and expected outcomes under the “Mención Industrial” distinction [8].

Pathway	Recruitment	Technology Readiness Level (TRL)	Funding	Supervision	Training	Main Research Environment	Career Prospect
Academic PhD	University	1–3	University-funded or scholarship	Doctoral supervisors	Doctoral courses and seminars	University Laboratory	Academia or mixed
Industrial PhD (Mención Industrial)	University + Company	3–7	Contract with company	Academic supervisor + industrial mentor	In-house training	University + Company Facilities	Strong industry integration

Besides Spain, other European countries have developed their own approaches to organizing industrial doctoral training. Some models place more weight on the company side, while others try to balance responsibilities more evenly between universities and industry. In parallel, structured training programmes, such as those developed within Marie Curie networks, have shown that combining academic and industrial environments can work well when properly coordinated [10], particularly in the context of more application-oriented knowledge production [1,11]. Against this background, this paper focuses on the Spanish model and places it in a broader European context. The purpose of this study is not to evaluate the relative performance of national industrial doctorate programmes or to establish causal relationships between funding models and innovation outcomes. Instead, it adopts a comparative conceptual approach in which a small number of Western European systems are examined as illustrative reference cases to identify features that may inform future development of the Spanish model. This study is consistent with the use of comparative analysis as a tool for theory development and policy discussion rather than statistical inference [12,13].

1.2. Training Ecosystem of the “Mención Industrial” in Spain

The industrial doctorate model in Spain is structured around a relatively clear framework, although its practical implementation involves several interacting elements. As summarized in Figure 1, the system is anchored in a regulatory framework that defines the main conditions for doctoral training, including supervision requirements, training activities, and the need for a formal collaboration agreement between the university and the company [8]. At the same time, national policy priorities continue to strengthen links between research and industry, particularly through mechanisms that enhance knowledge transfer [14].

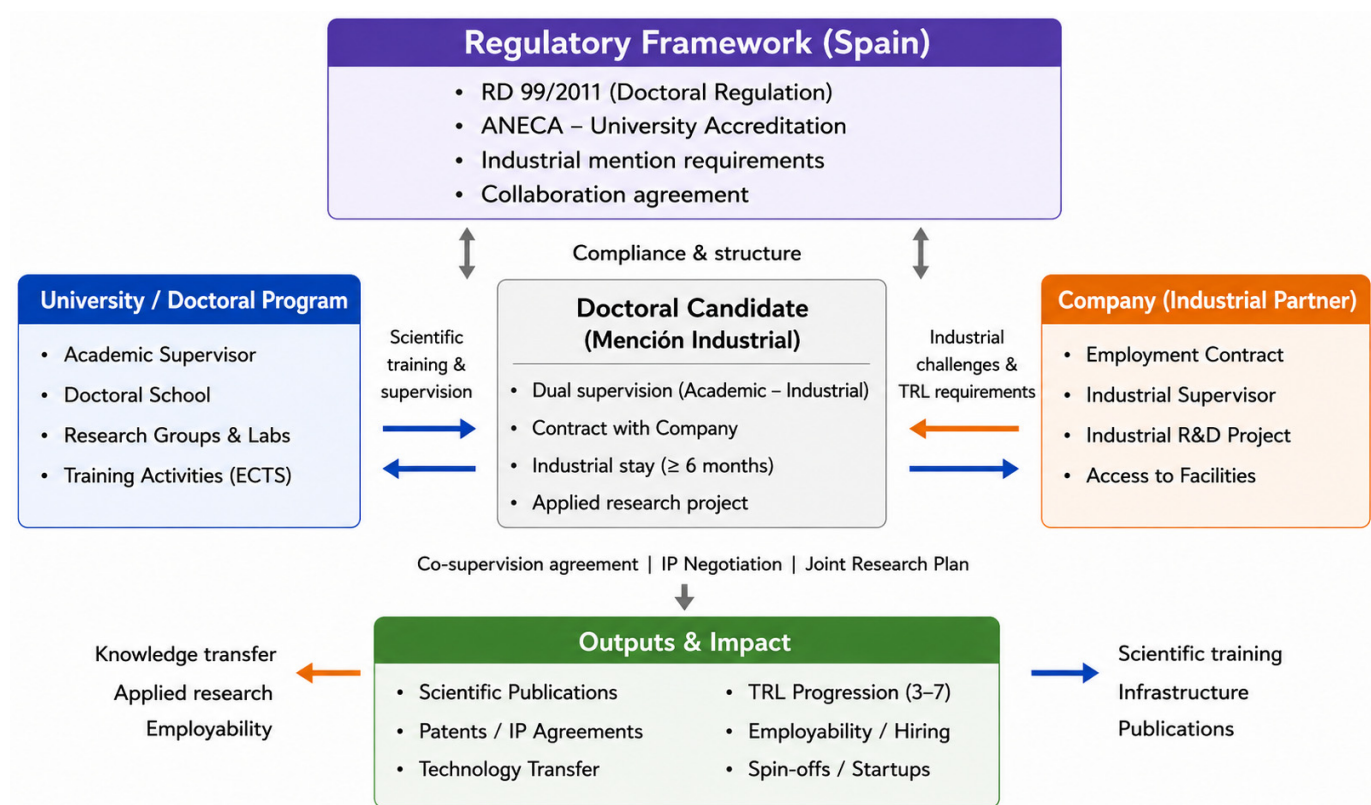


Figure 1. Ecosystem of the Spanish industrial doctorate (“Mención Industrial”) showing the regulatory framework, co-supervision structure, training activities, university–company interactions, and expected academic and industrial outcomes [8]. Source: The author’s own work.

The “Mención Industrial” distinction requires continuous interaction between academic and industrial partners. The level of company engagement is not necessarily uniform across all industrial doctorates. Although the regulatory framework establishes common requirements, the intensity of industrial participation may vary depending on the degree of integration between the academic and industrial environments. Universities are primarily responsible for scientific quality, research training, and doctoral assessment, whereas companies provide access to higher-TRL challenges, industrial facilities, and application-oriented research environments. The doctoral candidate therefore simultaneously develops as a researcher and as an innovation professional. On the university side, the doctoral programme provides scientific supervision and training activities accredited with European Credit Transfer and Accumulation System (ECTS), while on the company side, the candidate is usually employed under a contract and works within an R&D context. This dual structure requires continuous coordination between both environments. An important component is exposing the candidate to real industrial challenges through a period of activity in the company for at least one year. This can be seen as a form of advanced work-based learning, where academic and practical skills develop in parallel [4].

The outcomes reflect this dual nature, combining academic outputs (e.g., publications) with industrial outputs (e.g., intellectual property (IP) agreements, patents, and technology transfer). However, even if the purpose is well defined, its effectiveness depends on how these elements are coordinated in practice.

This study has three main objectives. First, it examines the Spanish industrial doctorate distinction (“Mención Industrial”) and its role in linking doctoral research with industrial practice. Second, it compares the Spanish model with selected programmes in France, Denmark, and the United Kingdom to identify differences in funding, supervision, and collaboration between universities and companies. Finally, drawing on this comparison, it discusses a possible refinement of the Spanish system through a dual-funding approach that may contribute to the long-term sustainability of university–industry collaboration and doctoral training ecosystems.

2. Method

This study takes a simple comparative approach with a clear focus on Spain. The main interest is the “Mención Industrial” and how it is currently being used to connect doctoral training with industry. To make sense of its strengths and limitations, the Spanish model is examined alongside three other European cases: France, Denmark, and the United Kingdom. Following recommendations for the small-N comparative approach, the selected cases are treated as illustrative reference systems and not as representative samples from which causal inference can be drawn [12,13].

The selected countries represent different but well-established approaches to industrial doctoral training in Western Europe. France was chosen because of its long-standing CIFRE programme, Denmark for its structured dual-funded model, and the United Kingdom for its flexible collaborative schemes. Together, these cases provide useful reference systems for examining the Spanish model. The comparison combines qualitative and quantitative indicators. The qualitative analysis considers funding arrangements, employment model, public funding allocation, and the level of university–industry integration. The quantitative indicators include patents per million inhabitants, public–private co-publications, industry-funded doctoral candidates, and business expenditure on R&D (BERD). These indicators were selected to provide context for the structural comparison rather than to measure programme performance directly. Depending on the country, the reported values may include doctoral candidates employed by companies, recipients of industry-supported doctoral funding, or participants in structured university–industry doctoral schemes. The

data are mainly obtained from the OECD and European Commission sources, together with national-level reports, including regularly updated statistical series [14–18].

Terminology. Throughout this paper, the term industrial doctorate refers to structured doctoral programmes that formally integrate university and industry through joint supervision and industrial participation. The terms industrial PhD and industry-funded doctoral candidate are used interchangeably to describe doctoral researchers undertaking their training with industrial funding or employment. However, when used in relation to statistical indicators, these terms should be interpreted as an approximate measure of industrial involvement in doctoral training rather than as a direct count of formal industrial doctorate programmes, since national datasets may also include other forms of industry-supported doctoral training.

3. Comparative Context and Illustrative Indicators

Figure 2 shows the values of the KPIs described in the methodology for Spain, France, the UK, and Denmark. The indicators presented in this section are included to help place the selected industrial doctorate systems into context. They are not intended to demonstrate that particular funding models directly lead to stronger innovation performance. Cross-country differences reflect a combination of factors, such as business expenditure on R&D (BERD), industrial structure, patenting behaviour, economic scale, and national innovation policies. Accordingly, the indicators are used to inform a conceptual comparison.

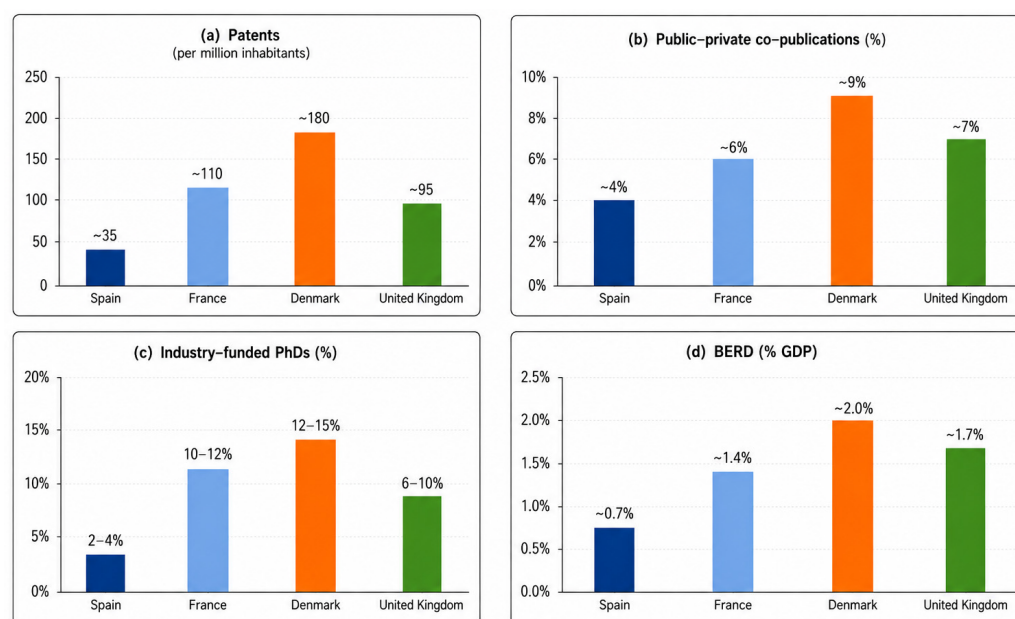


Figure 2. Comparison of research and innovation indicators across Spain, France, Denmark, and the United Kingdom. (a) Patents per million inhabitants. (b) Public-private co-publications (%). (c) Industry-funded doctoral candidates (%). (d) Business expenditure on research and development (BERD, % GDP). Sources: (a) OECD Patent Statistics [16]; (b) European Innovation Scoreboard 2023, public-private co-publications indicator [19]; (c) ANRT (France), Innovation Fund Denmark, and UKRI and AEI reports [14]; and (d) OECD Main Science and Technology Indicators 2023, BERD as % GDP (2023) [16].

The indicators presented in Figure 2 complement the structural comparison with a quantitative view. The differences are noticeable, even if the exact values should not be over-interpreted. Denmark tends to appear at the upper end in most of these indicators, with around 180 patents per million inhabitants, close to 9% of public-private co-publications, and an estimated 12–15% of doctoral candidates involved in industry-funded programmes.

France also shows relatively strong values, particularly in patent activity, which is typically around 110 per million inhabitants, and in the share of industry-funded doctoral candidates, which is typically reported in the range of 10–12%.

The United Kingdom sits somewhere in between, with approximately 95 patents per million inhabitants and a proportion of industry-funded doctoral candidates that can vary between 6% and 10%, depending on the programme. Spain, in comparison, remains at lower levels across most of these indicators, with roughly 35 patents per million inhabitants, around 4% of public–private co-publications, and a smaller share of industrial doctorates, generally estimated between 2% and 4%. These values should be read as an estimation, but they still provide a fairly clear sense of how differently industrial doctoral training is embedded in each national system and are broadly consistent with wider innovation indicators reported at the European level [19].

Table 2 provides a simplified overview of these differences, focusing on key aspects such as funding structure, the role of universities and companies, and the degree of integration between both environments. These variations have been discussed in the context of collaborative doctoral education across Europe [20], though they become more visible when systems are examined side by side [2,21].

Table 2. Comparison of industrial doctorate models and penetration in selected countries.

Country	Main Programme(s)	Who Employs Candidate	Who Receives Public Funding	Direct Public Funding to University	Estimated Industry-Funded PhDs (%)	System Characterization
Spain	AEI Industrial Doctorates + Mención Industrial	Company/ Entity	Mainly company (salary-focused)	No (indirect only)	2–4%	Emerging, under-scaled
France	CIFRE	Company	Company (state subsidy to employer)	No (indirect via collaboration)	10–12%	Centralized, company-centric
Denmark	Industrial PhD Programme	Company + University	Company + university	Yes	12–15%	Dual-funded, structured
United Kingdom	CASE, EngD, CDT (Industrial Subset)	Mixed (University or Company)	Mainly university + industrial co-funding	Yes (via grants)	6–10%	Distributed, flexible

The “Direct Public Funding to University” column indicates whether the programme provides explicit financial support to universities for activities associated with industrial doctoral training, such as supervision, research infrastructure, or specialized training. In Denmark and most UK schemes, universities receive dedicated programme funding. In contrast, in Spain and the French CIFRE programme, public funding is directed primarily to the employer, while universities support doctoral training mainly through existing institutional resources. Part of these differences can be traced back to how doctoral candidates are funded and how responsibilities are distributed. In Spain, the company typically takes primary responsibility for funding the doctoral candidate during the program. This tends to place the industrial partner at the centre of the funding structure. The French CIFRE scheme is more structured, with public funding directly supporting the company while maintaining a strong link to the academic system [22], as also highlighted in national evaluations of the CIFRE scheme [23]. Denmark, by contrast, follows a more balanced approach, where both the university and the company are explicitly involved in funding and supervision, something that has been analyzed in detail in evaluations of its industrial PhD programme [24].

In the United Kingdom, the situation is somewhat more diverse. There are several schemes in place, including collaborative doctoral partnerships, CASE studentships, and doctoral training centres. In many cases, funding is channelled through universities, often combined with contributions from industrial partners, although the exact balance can vary depending on the programme [25]. This results in a more flexible and less uniform system.

The degree of integration between academic and industrial activities also differs across countries. In Spain, the requirements for collaboration are defined, but their implementation can vary significantly across projects and partners. In France and Denmark, interaction between the two environments tends to be more standardized, with clearer expectations for co-supervision, mobility, and alignment of objectives. In the UK, some programmes offer strong and continuous interaction with industry, while others remain closer to a traditional academic model, even if they include elements of collaboration.

Beyond formal funding arrangements, the way industrial doctorate programmes are presented also provides insight into the roles assigned to universities and companies. In Spain, information published by the national funding agency primarily describes these programmes in terms of company-based employment, industrial R&D activities, and the incorporation of doctoral researchers into the productive sector [26]. Likewise, guidance prepared by universities for prospective industrial partners typically focuses on industrial collaboration and the funding available to employers [27]. Academic supervision and doctoral training remain essential requirements, but they are generally presented as part of the regulatory frame rather than as activities receiving dedicated financial support [28]. This pattern is also reflected in recent recruitment advertisements. For example, the University of Alicante provides dedicated funding to support research expenses associated with industrial doctoral supervision [29], illustrating that some universities have already recognized the need to better align institutional responsibilities with available resources. In a similar example, an industrial doctoral position highlighting an academic–industry collaboration challenge focused on new carbon capture technologies was jointly sponsored by Universidad Loyola Andalucía and the company GHENOVA [30]. These examples indicate how there is a growing need to establish more balanced funding models in Spain.

From a training perspective, these differences are not just administrative. They shape how doctoral candidates experience their workday. In systems where integration is stronger, industrial collaboration is not simply an additional component, but a central part of the training pathway [31,32]. This often leads to a clearer link between research objectives and industrial needs and, in many cases, to more direct career opportunities. In systems with less structured integration, there may be greater flexibility but also greater variability in the amount of industrial exposure the candidate actually receives.

Overall, the comparison suggests that the way funding and responsibilities are shared plays an important role in the development of these programmes. Countries with more balanced or better-defined structures are also those that frequently report higher levels of participation in industrial doctorate programmes and collaboration indicators. While this association is noteworthy, it should not be interpreted as evidence that funding structure alone explains these differences. This does not necessarily imply that one model is universally preferable, but it does point to certain elements that may help explain why some systems are more successful than others. These observations provide a useful starting point for considering possible adjustments to the Spanish model, which are further explored in the following section.

4. Discussion

Industrial doctorates can be viewed as mechanisms that support the long-term circulation of knowledge, skills, and innovation between universities and industry. Beyond their

educational function, these programmes contribute to the development of human capital, strengthen knowledge transfer pathways, and help create more sustainable innovation ecosystems. In this sense, the sustainability of industrial doctorate schemes depends not only on their educational outcomes but also on their ability to maintain durable collaborations between academic and industrial partners. The comparison presented in the previous section helps to place the Spanish industrial doctorate model in a broader context, but it also raises a more practical question: what is actually limiting its adoption? The comparison suggests that the issue is not so much the absence of a framework, since the “Mención Industrial” already provides a clear structure, but rather the distribution of responsibilities and resources among the different actors involved.

One aspect that stands out is the way funding is currently organized. In Spain, public support is largely directed toward the industrial partner, mainly to cover the salary of the doctoral candidate. While this approach has the advantage of reducing the financial barrier for companies, it does not fully reflect the university’s role in the training process. As discussed earlier, supervision, research infrastructure, and doctoral training activities remain primarily academic responsibilities, yet they are not directly supported within the same funding scheme, especially taking into consideration the low cost of registration fees for doctoral students in Spain. In practice, this creates a situation in which the collaboration is clear but not fully reflected in how resources are allocated. This type of imbalance has also been observed more broadly in studies of university–industry engagement, where academic contributions are sometimes less visible in financial terms [33,34]. Looking at other countries helps to clarify this point. The French CIFRE model, for example, provides a structured and well-established framework, with centralized management and standardized agreements that contribute to its consistency over time [22]. However, even in this case, funding remains largely linked to the company, and the academic contribution is supported more indirectly. Denmark, on the other hand, moves closer to a shared structure in which both the university and the company are explicitly involved not only in supervision but also in funding [24]. This tends to create a more balanced environment, at least in terms of how responsibilities are formalized, which is a pattern also observed in comparative analyses of Nordic industrial PhD schemes [35].

Effective collaboration typically relies on defined responsibilities between academic and industrial partners. In most successful schemes, universities retain responsibility for academic quality, research training, and degree requirements, while companies provide the industrial environment with higher TRL challenges and day-to-day professional integration. Co-supervision arrangements and regular progress meetings are frequently cited as important mechanisms for maintaining alignment between academic and industrial objectives [34]. The rationale behind the model proposed in Figure 3 extends beyond the redistribution of financial resources. Effective industrial doctorate programmes also depend on sustained interaction between universities and companies throughout the doctoral journey. Previous studies have shown that regular collaboration helps create environments where knowledge can move more easily between academic and industrial settings, increasing the likelihood that research outcomes will find practical application. By encouraging a more balanced involvement of both partners, the framework proposed in Figure 3 may also strengthen knowledge transfer activities and provide doctoral candidates with broader professional networks and a deeper understanding of how innovation develops in practice [28,30]. The United Kingdom presents a more varied picture. Different schemes coexist, and the level of industrial involvement can differ depending on the programme. In many cases, funding is channelled through universities, often combined with industrial contributions, which introduces a degree of flexibility but also some variability in how collaboration is implemented [25].

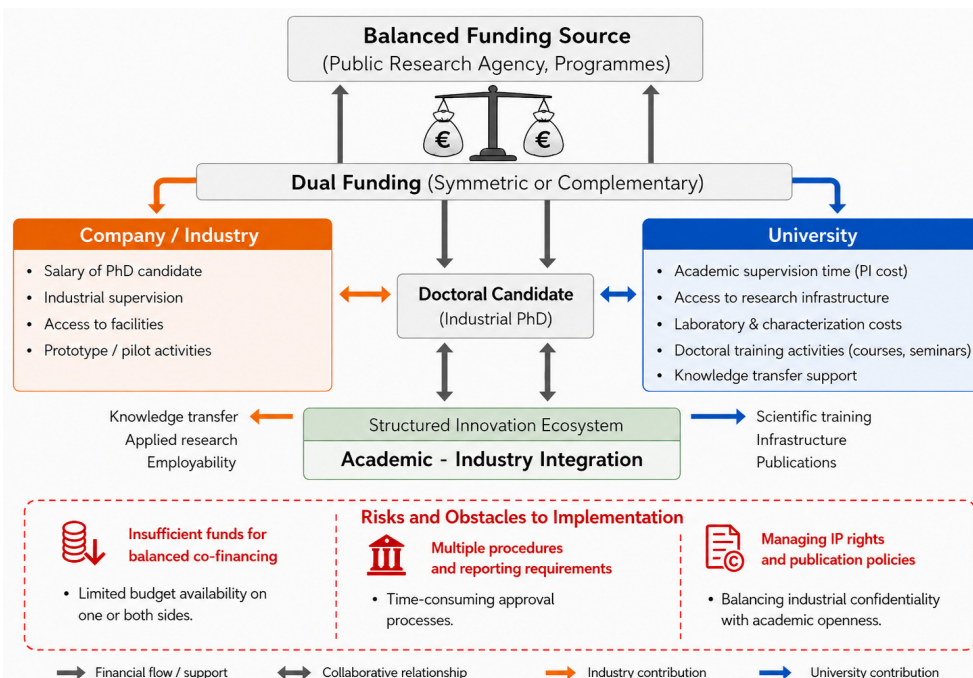


Figure 3. Conceptual diagram of the proposed dual-funded model for industrial doctorates in Spain, where both the industrial partner and the university receive dedicated funding to support a doctoral student. Source: The author's own work.

The Spanish model does not appear fundamentally misaligned, but it seems to be incomplete. The structure is in place, and the interaction between academic and industrial environments is clearly defined, but the distribution of resources does not fully match this shared responsibility. This is where the idea of a dual-funded model becomes relevant. As shown in Figure 3, the proposal does not involve introducing a completely new system, but adjusting the existing one so that both the industrial partner and the university are recognized as direct participants in the funding scheme. The proposed adjustment would also involve practical challenges, including more time-consuming approval processes, limited public funding for co-financing, and the management of intellectual property and publication policies. Implementing a dual-funding model would not necessarily require the creation of an entirely new funding scheme. Instead, it could build on the existing framework by introducing a complementary contribution that supports university activities directly associated with doctoral training, such as supervision, research infrastructure, and specialized training. Similar principles can be found in the French CIFRE scheme and the Danish Industrial PhD Programme. While the exact level of support would ultimately depend on national priorities and available resources, a gradual implementation could improve alignment between responsibilities and funding. The proposed strategy involves allocating resources in a way that reflects the contributions of both sides, covering not only employment costs but also supervision, infrastructure, and training activities. The rationale behind this approach is relatively straightforward. Industrial doctorates are, by definition, a joint effort. The doctoral candidate operates across both environments, receives guidance from both academic and industrial supervisors, and contributes to outcomes relevant to both contexts. This dual positioning has been widely discussed in the literature on doctoral training at the university–industry interface, particularly in relation to supervision, career development, and longer-term professional trajectories [36,37].

The proposed dual-funding model should not be interpreted as being derived from the Danish programme alone. Instead, it emerges from the broader comparison presented in this study and from the observation that industrial doctorates are most effective when

funding responsibilities are aligned with the contributions of both universities and companies. Denmark illustrates one possible way of achieving this balance, but the proposal is intended as a general conceptual frame that could be adapted to the specific characteristics of the Spanish system.

If implemented successfully, this approach could reduce current imbalances and make industrial doctorates more attractive to both universities and companies. This is consistent with views of innovation systems that emphasize the importance of interaction between universities, industry, and public institutions, as well as the sustainability of collaborative relationships over time [1,34,38]. Such interactions are widely recognized as important mechanisms for knowledge transfer and innovation, particularly when academic research can be translated into industrial applications and societal value [39,40]. At the same time, it may help clarify expectations between partners, which is often a source of variability in how these programmes are implemented.

Of course, it would be unrealistic to expect that changes in funding alone would fully transform the system. Other factors, such as institutional culture, administrative processes, and the maturity of knowledge transfer, also shape how industrial doctorates function in practice. In some cases, these aspects may even be more decisive than the funding model itself. For that reason, the dual-funded approach should be seen as one possible step toward improving the system, rather than a complete solution. Its implementation would likely depend on institutional conditions that are not always easy to standardize.

5. Conclusions and Limitations

This paper argues that the effectiveness of industrial doctorates in Spain depends not only on the existence of a regulatory framework but also on how responsibilities and resources are shared between universities and companies. By comparing the Spanish model with selected programmes in France, Denmark, and the United Kingdom, the current study highlights the importance of aligning funding structures with the collaborative nature of industrial doctoral training.

The analysis suggests that Spain has developed a suitable framework for the industrial doctorate distinction, yet direct financial support remains focused mainly on the industrial partner despite the significant contribution of universities through supervision, training activities, and research infrastructure. On this basis, a dual-funding approach is proposed in which both companies and universities receive explicit support. This adjustment could strengthen collaboration and contribute to the long-term sustainability of industrial doctoral training ecosystems.

Future research could also examine factors beyond funding. Universities and companies may differ in their willingness or capacity to host industrial doctoral candidates because of organizational priorities, administrative procedures, or available resources. The effectiveness of technology transfer offices and the quality of collaboration between academic and industrial supervisors may also influence programme outcomes. Future studies based on interviews, case studies, or broader comparative analysis could help explain how these factors interact and shape the long-term success of industrial doctorate programmes.

This work primarily relies on publicly available information and a limited set of comparative indicators, and the selected countries should therefore be considered illustrative reference cases rather than a comprehensive international sample. Future research could complement these findings through interviews, surveys, and detailed case studies that provide a deeper understanding of how industrial doctorates operate in practice and which factors most strongly influence their adoption.

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