

Industrial doctorates for regional development: the case of Le Marche Region

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Abstract

Over the past decade, there has been a steady increase in the number of industrial PhD programmes (IPPs) at the global level, especially in advanced countries. Several regional and national governments have invested considerable resources to set up and support IPPs which have been presented as strategic policy tools for promoting the employability of doctorate holders outside academia, for supporting innovation, and for building bridges between universities, industry, and society at large. Nevertheless, empirical evidence about the impacts of IPPs has so far been either limited or inconsistent. This longitudinal study presents the industrial PhD programme *Eureka* which was enacted between 2012 and 2020 by the regional government of an Italian region (Le Marche). The analysis considers 499 industrial PhD scholarships that were co-financed by the regional government, along with the four regional universities and more than 200 firms that have headquarters in the region. The paper provides a retrospective long-term overview of the impact of *Eureka* on PhD holders' employment and reveals the characteristics of the firms that participated in the IPP. Policy implications and recommendations are derived from this.

Keywords Doctoral education \cdot Industrial doctorate \cdot Industrial PhD \cdot Industrial policy \cdot Innovation \cdot University-industry collaboration

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Introduction

The rise of the knowledge economy and digitalisation, along with the effects of financial, economic, and environmental crises, have contributed to redesigning and extending the missions of universities. There has been growing pressure to open universities to the socioeconomic ecosystem and to fulfil the so-called Third Mission (Compagnucci & Spigarelli, 2023; Vorley & Nelles, 2009). Within this framework, universities are expected to act as vectors of knowledge transfer (Compagnucci & Spigarelli, 2020; Marinelli et al., 2018), and co-creators of knowledge along with non-academic actors, promoting lifelong learning, public engagement, and citizen science (Laredo, 2007). Industrial PhD programmes (hereinafter IPPs) have been playing an important role in implementing this mission as they involve collaboration between higher education institutions and firms (Mills & James, 2020; Tavares et al., 2020).

Although the 'traditional' PhD has frequently been considered to be the starting point for an academic career for a long time (Wildy et al., 2015), the lack of faculty positions (Cardoso et al., 2019b) and the need for new skills to deal with rapid changes in the labour market (Tavares et al., 2019) have encouraged universities, governments, and firms to develop IPPs. In recent years, there has been a steady increase in the number of IPPs, contributing to the transformation of doctoral education (Cardoso et al., 2022; Sarrico, 2022). Several governments, especially in Europe, have set up schemes to support IPPs (Tavares et al., 2020) which have been presented as strategic policy tools (Assbring & Nuur, 2017) for building bridges between academia and industry (Roolaht, 2015), for promoting the employability of PhD holders (Cardoso et al., 2019b), and—more ambitiously—for contributing to the growth of regional innovation ecosystems (Marinelli et al., 2018).

Acknowledging that IPP regulations, objectives, and content may well vary from country to country (Granata & Dochy, 2016; Yang & Jeffrey, 2021), this study focuses on IPPs that involve cooperation between universities, firms, and regional governments, so as to improve the employability of PhD candidates. Such collaborations may take different forms but still retain some common features. Universities and firms co-design the research programme that usually starts by identifying a challenge within a business organisation or an industry. They then share the costs of funding the PhD scholarship, research facilities (Cardoso et al., 2019b), and doctoral supervision (Salminen-Karlsson & Wallgren, 2008). Most IPPs last, on average, for 3 to 4 years, and PhD students spend a considerable part of their time (usually half) working at the firm even whilst they are conducting research at the university to fulfil doctoral tasks (Casano, 2015).

There is little systematic organisation of both information and data on IPPs across countries. Furthermore, knowledge of the impacts of IPPs is either limited or inconsistent (Compagnucci & Spigarelli, 2024). Indeed, there is a lack of longitudinal studies on the effects of IPPs on PhD candidates' formation, employment, and career development (e.g. Bernhard & Olsson, 2020; Cardoso et al., 2019a; Tavares et al., 2020). It is worth noting that both the characteristics of national contexts and the scientific specialisations of IPPs also influence candidates' career prospects in terms of sector of employment (Moghadam-Saman, 2020). Moreover, there is limited understanding of the characteristics of the companies that participate in IPPs (Assbring & Nuur, 2017; Bernhard & Olsson, 2020; Grimm, 2018). There is also scant empirical evidence regarding collaborative practices for implementing IPPs (Cardoso et al., 2019a).

The literature has recently reported that there are still both institutional and cultural barriers to the diffusion of IPPs (Bernhard & Olsson, 2023; Compagnucci & Spigarelli, 2024). As regards institutional barriers, there is lack of appropriate funding schemes (Borrell-Damian et al., 2010). Funding implies complex negotiations between the actors who may have heterogeneous values, and interests, at stake. As for cultural barriers, there is limited understanding of the long-term dynamics at work in the collaboration between universities, firms, and governments involved in IPPs (Gustavsson et al., 2016; Yang, 2022). Moreover, academics often consider IPPs as an alternative to traditional PhDs (Harman, 2002, 2004) or even as less valid (Jaakkola et al., 2021), whilst firms are usually reluctant «to hire PhDs because they are overqualified and too independent» (Hankel, 2019, p. 1).

To contribute to dealing with the above-described research gaps, this study investigates the features of an IPP, entitled *Eureka*, and its impact on PhD holders' employment. The study also reveals the characteristics of the firms that participated in the programme. Nine editions of *Eureka* were enacted between 2012 and 2020 by the regional government of the Marche region (*Le Marche*), in Italy. This empirical analysis considers 499 PhD candidates, the 4 universities in the region and 243 firms that have headquarters in Le Marche. The IPP was based on a co-funding scheme that involved the regional government, firms, and universities. This co-financing scheme has been modified occasionally over the years.

This study offers a threefold contribution that may be of interest to scholars, practitioners, and policymakers. First, it adds to the theoretical and empirical understanding of the transformation in the form and content of doctoral education (e.g. Cardoso et al., 2022; Grant et al., 2022; McAlpine et al., 2020; O'Carroll et al., 2012; Sarrico, 2022) by delving into the underexplored field of IPPs (Cardoso et al., 2019a; Mills & James, 2020; Tavares et al., 2020; Thune, 2009). Second, it provides the first retrospective long-term overview of the *Eureka* IPP by exploring its impact on PhD holders' employment overall, as well as the features of funded PhD scholarships and of the firms participating. Third, since there is a need to identify a set of common good practices generated by IPP partnerships (Granata & Dochy, 2016; Yang, 2022), this paper proposes a selection of suggestions for improving the alignment of doctoral education and innovation policies, and for strengthening collaboration between academia, companies, and governments within the local innovation ecosystem.

The paper is structured as follows. 'Industrial doctorates as policy tools' reviews the literature related to industrial doctorates. 'Data and methodology' illustrates the data and methodology. 'Context of the study and preliminary results' describes the context of the study and preliminary results.' Descriptive statistics' contains the descriptive statistics followed by the 'Results and discussion' section. The 'Conclusion, policy implications, and avenues for future research' are then described.

Industrial doctorates as policy tools

IPPs have attracted increasing attention from both scholars and policymakers over the last decade (Sin et al., 2021). They have changed doctoral education especially as regards the mechanism through which knowledge can flow between university, industry, government, and society, making the boundaries of doctorates even more porous (Cardoso et al., 2022). However, IPPs usually offer benefits for all these stakeholders (Lindén & Björkman, 2019; Yang, 2022). In particular, IPPs are able to build bridges between the academic and the business sector, by addressing competence gaps at company level (Cardoso et al., 2022; Lindén &Björkman, 2019), by developing collaborative and cross-sectoral research (Prøitz & Wittek, 2020), and by guiding graduates towards non-academic careers (Manathunga et al., 2012).

The literature has placed partnerships for IPPs within the triple helix model (THM) of innovation (Assbring & Nuur, 2017; Thune, 2010; Wallgren & Dahlgren, 2007; Yang, 2022), which is increasingly being adopted as a source of inspiration for local development policies, that seek to improve the conditions for innovation (Etzkowitz & Zhou, 2018). Within this framework, governments often mediate the interactions between universities and business organisations (Granata & Dochy, 2016), by engaging them in a continuous entrepreneurial discovery process for building knowledge and designing strategies accordingly (Assbring & Nuur, 2017). Nevertheless, there is still limited quantitative evidence about the long-term impacts of IPPs on PhD students, firms, and—more broadly—on local ecosystems, especially in the case of Italy; however, such evidence may be crucial for improving both the design and the coordination between education and innovation policies (Marinelli et al., 2018).

In France, Guillouzouic and Malgouyres (2020) have analysed the effects of the *Conventions industrielles de formation par la recherche* (Cifre) programme on both PhD candidates and on participating firms. Under the Cifre agreement, the French government provides financial support to any socio-economic actor, that is based in the country, that recruits doctoral students for developing research projects. Findings have revealed that, at the individual level, industrial PhD candidates, especially those in the engineering field, are more likely to have obtained a permanent contract 3 years after completing their PhD. Furthermore, industrial candidates have, on average, higher salaries when compared to other PhD students. However, industrial PhD candidates are less likely to publish their research outcomes in peer-reviewed journals. At the company level, small firms that hosted PhD students recorded an increase in the number of collaborators involved in R&D activities.

As part of its evaluation policy, the Danish Agency for Science Technology and Innovation (2011) has performed an econometric exercise to assess the Danish Industrial PhD Programme which was funded by the Danish Council for Technology and Innovation. This programme aimed to increase knowledge sharing between universities and private firms, to promote research for commercial aims, and to take advantage of competences and research facilities in private business organisations so as to increase the number of PhD holders. According to Danish regulations, doctoral candidates should be employed by a public or private company whilst they are also enrolled at the university. The student divides her/ his working hours between the company and the university (Danish Ministry of Higher Education & Science, 2017). The Danish Agency report explored both the impact of the IPP on the salary and career characteristics of 430 PhD candidates and the performance of the 270 participating firms, in the period 1997–2006. As regards PhD students, the analysis compared both the salaries and type of work of industrial PhD graduates with both traditional PhDs and with individuals who have a university degree. As regards the firms involved in the IPP, the study investigated developments using four parameters: the number of patents, gross profit, employment growth, and total factor productivity. Findings revealed that, on average, industrial PhD holders earned 7-10% higher salaries than did either regular PhD holders or university graduates. Furthermore, they were more likely to be employed at higher levels in the hierarchy of their organisations than were regular PhDs. Also, industrial PhDs were more likely to be involved in positions requiring high-level specialist knowledge than university graduates. Firms that host industrial PhD projects had, on average, increased their patenting activity. Moreover, such firms showed high growth in gross profit and employment.

Regarding the case of Italy, there is a lack of empirical studies about IPPs because such programmes are quite new within the Italian education system. However, a study by Marinelli et al. (2018) which offered some interesting insights into the regional IPP started in Puglia in 2016 is worth mentioning. From the methodological standpoint, the authors performed a qualitative study by drawing on the results obtained from an exploratory workshop and interviews with a small sample of professors responsible for industrial PhDs, regional policymakers, PhD candidates, and representatives of firms involved in the doctoral programme. Findings revealed that a cross-disciplinary approach to doctoral training was the main feature that made this IPP both attractive and challenging. The universities highlighted the need to introduce important bureaucratic and organisational adjustments in the management of the IPP. Furthermore, scholars revealed that they had to put more effort into supervising industrial PhDs since such doctoral programmes require a shift from basic to applied research and had also to be aware of the interests at stake for both the firms and the other actors operating in the innovation ecosystem. At the level of firms, the main challenges were related to the development of students' soft skills and the definition of a joint research project since small and medium-sized enterprises (SMEs) usually have less propensity to engage in R&D than larger companies. Networking, communication, and information flows between the programme's stakeholders proved crucial for improving teaching and learning and for achieving academic formal requirements such as dissertation tasks and work-based visiting periods abroad.

Data and methodology

This retrospective long-term overview of the nine editions of the *Eureka* IPP relies on data that were collected from both primary and secondary sources. The research was based on three steps.

Firstly, we collected secondary data from both the regional government and the 4 universities that operate in the region: the Polytechnic University of Marche (Università Politecnica delle Marche, UNIVPM), the University of Macerata (Università degli Studi di Macerata, UNIMC), the University of Urbino (Università degli Studi di Urbino Carlo Bo, UNIURB), and the University of Camerino (Università degli Studi di Camerino, UNICAM). The first version of the dataset was constructed by the authors and included the following information on 499 PhD candidates: the names of the students, the date they enrolled in the programme, the date they obtained their PhD, and their field of study. The dataset also reported the names of the firms that participated in the IPP.

Secondly, in order to collect further information on the profiles of PhD candidates, such as their occupation before enrolling in the IPP and their employment after graduating, we used *LinkedIn*, the largest professional network on the Internet. A scraping technique was applied in order to extract profile information for a sample of about 370 PhD students, i.e. 75% of the total sample.¹ The algorithm was also used to retrieve information on both the co-funding firms and on the current employers of the PhD holders. The data on these firms were then matched with the AIDA Bureau Van Dijk database, which provides information on the size of firms, their location, and their sector of economic activity.

¹ Not all the PhD students have a *LinkedIn* profile. Moreover, the sample excludes PhD candidates who started their programme in 2020 since they will defend their doctoral thesis in 2024.

The third step consisted of organising a focus group (Hakim, 2000) to present the preliminary results of the research and to obtain clarification regarding some features of the IPP. The focus group was held in December 2023. Twenty people participated, amongst which were the stakeholders involved directly in *Eureka*: academic supervisors, representatives of firms, regional policy makers, and students who had completed the IPP. Such heterogeneity ensured both further insights into the characteristics of the programme and an exchange of good practices. The focus group lasted 2 h.

Context of the study and preliminary results

Since the early 2000s, there has been a surge in the number of PhD holders across the globe: policy makers have increasingly invested resources to train PhD students in order to contribute to addressing the new challenges posed by the labour market and to strengthening the competitiveness of their innovation ecosystems (McAlpine et al., 2020). Indeed, in 2019, the average share of 25–64-year-olds with a doctorate across the OECD countries was around 1% (Sarrico, 2022). In the case of Italy, the number of PhD holders was 1.1 per thousand individuals in the 25–34 age group in 2014 (ISTAT, 2018). In 2024, the country is still below the average for European Union (EU) Member States and performs less well than do Germany, Denmark, and France. Whilst Italian PhD candidates spend increasing periods abroad, only one PhD holder in ten works as a university professor or researcher; amongst those living abroad, this ratio is one PhD in four (ISTAT, 2018). Furthermore, the number of PhD graduates employed as researchers in Italian firms is lower than that of other EU advanced economies, such as Germany or France. The lower demand for PhD holders also depends on the characteristics of the Italian economic system which is mainly composed of small and micro companies with medium-low technological intensity. Such firms usually invest less resources in both R&D and in highly qualified human capital (Ballarino et al., 2021).

Overall, the role of doctoral education for non-academic purposes has been downplayed in Italy, since PhD courses are often considered as self-referential training mechanisms for prospective academics, rather than as a mechanism for promoting innovation and technology transfer (Tiraboschi, 2014). More recently, it has been demonstrated that gender is a discriminating factor in a PhD holder's career development, especially in the case of Italy (Carriero et al., 2024). In addition, the literature has emphasised that, in Italy, PhD education is still little understood either by firms or by the public administration where the role, and the competences, of PhD holders are either underrated or unrecognised at the local level (Ballarino et al., 2021). However, Italian legislators have tried to change this attitude towards doctorates by means of a set of actions that seek to encourage collaboration between academia and firms. Amongst these interventions, article 11 of Ministerial Decree n. 45 of February 8, 2013, introduced industrial doctorates which are categorised into three sub-typologies (a) doctorate in collaboration with firms, (b) industrial doctorate, and (c) doctorate in higher apprenticeship (Marinelli et al., 2018).

According to the 'National Research Programme 2015–2020' of the former Ministry of Education, University and Research (MIUR), IPPs should comply with at least one of the following requisites: (i) the university has an agreement with a company that performs research and development activities (R&D), with the possibility of reserving PhD positions for the firm's employees; (ii) within the framework of the 'traditional' PhD programme, the university activates PhD curricula managed jointly by the university and selected firms.

Decree n. 266 of December 14, 2021, introduced a set of measures to further strengthen doctoral education, especially IPPs. The Decree broadened the aims of doctoral education by highlighting the importance of involving PhD students in more innovation-driven research and knowledge transfer activities in collaboration with firms and public bodies. Moreover, the Decree emphasised cross-disciplinary and cross-sector training for PhD candidates. To do so, an IPP should be based on a consortium of universities, private and public research institutes, and companies that focus on R&D. Although the new national regulation acknowledges the key role of soft skills training, the Decree does not introduce compulsory project management courses nor marketing training which could be seen as necessary, especially for industrial PhD students, to align research objectives and project milestones with the needs of the business organisations participating in IPPs.

So far, the main experiences of IPPs in Italy have been at the regional level (e.g. Marinelli et al., 2018). From the point of view of regional governments, the aim of these IPPs is to ameliorate the regional ecosystem by supporting both the innovation capabilities of firms and their relations with the university system. The regional dimension of the analysis raises interesting questions about the role of IPPs within regional innovation policies, which have, so far, not been addressed in the literature.

After the programming period 2014–2020, all regions of the EU Member States were asked to design and enact their regional innovation policies according to the principles of the Smart Specialization Strategy (S3). This strategy requires regions to identify investment priorities and to concentrate resources on them. It would be interesting to examine whether, and to what extent, the current distribution of PhD scholarships is coherent with the S3 of the region. Although the allocation of funds may be limited to S3 priorities, the demand for PhD scholarships depends on the capacity of firms to absorb such PhDs which may not be the same in all S3 sectors. Under the S3 framework, coordination between human capital formation and innovation policy is crucial for the future of S3 itself (Marinelli et al., 2018). However, it is worth considering the differences between and within regions. Along with investing resources in the quality of tertiary education (as in the case of IPPs), regions with moderately developed innovation ecosystems should also strengthen the technological capabilities of their companies as a pre-requisite to improving the conditions for innovation (D'Este et al., 2013).

Eureka programme

Before the Italian National Recovery and Resilience Plan (NRPP) allocated considerable resources for implementing industrial and innovative doctorates in 2023, IPPs were not so well spread within the Italian education system. The regional government of Le Marche was a pioneer when it introduced *Eureka* in 2012. This IPP was implemented under two consecutive National Operational Programmes on Research and Innovation (2007–2013 and 2014–2020). Such programmes were co-funded by the Regional Development Fund (ERDF) and the European Social Fund (ESF).

To better understand, and outline, the PhD policy implemented by this regional government, it is important to highlight the key features of the economic context of the Region, along with its strengths and weaknesses. Le Marche is a manufacturing region characterized by the presence of low and medium-tech sectors—such as textile and clothing, footwear, furniture, agri-food industries, and household appliances—and by the large number of employees active in small and micro firms. Here, private spending in R&D is below the national average and the prevailing innovation model relies on learning by doing and on interactions with customers and suppliers. However, the region has four universities with a total of about 50,000 students enrolled.

In this context, the main goals of *Eureka* were to strengthen the innovation capabilities of firms and to boost cooperation between companies and research institutions through joint applied research. As a result, *Eureka* was designed, and then improved, as a policy tool for enacting the regional Smart Specialisation Strategy. Furthermore, this IPP aimed to retain talents by diversifying their role within the labour market and by encouraging their employability in the region.

The co-funding scheme for each *Eureka* PhD scholarship involves the regional government, one university based in the region, and one firm with headquarters operating in the same geographical area. Both the co-funding structure of this IPP and the PhD scholarship funds have been modified a few times during the nine editions of *Eureka* (Table 1). Also, the priority areas/domains of innovation involved in *Eureka* have been adjusted to align with the Regional Smart Specialization Strategy. Whilst in the first four editions the regional government, the university, and the firm equally co-funded 1/3 of the scholarship; later, the government and the universities decided to make some changes to the programme. The financial contribution for firms was reduced to 1/5, the salary and research budget for students were increased to comply with new national regulations, whilst the number of PhD scholarships was reduced. Changes were necessary in order to increase the participation of small firms in the programme, to better attract talents, and to match the capacity of the regional ecosystem to absorb them better. Moreover, starting from 2018, a new type of IPP, namely the *Innovative doctorate programme*, was introduced with PhD scholarships totally financed by the Region and targeted clusters of firms instead of individual companies.

Table 1 offers an overview of the *Eureka* programme and the evolution of its co-funding scheme which involved 243 firms.

Eureka is based on an annual public selection process that is carried out in three steps: (i) launch of a call for applied research proposals jointly prepared by a company—with headquarters in Le Marche—and one of the four universities in the region; (ii) given a set of quantitative and qualitative criteria defined by the regional government, the latter evaluates and then, selects a limited number of research proposals co-presented by universities and firms; (iii) given the research proposals accepted for funding, each university publishes a call for PhD applications and organises the selection process of candidates.

As for PhD students, applications are open to unemployed graduates who have been resident, or domiciled, in the region for at least 6 months before the publication of the call for PhD applications. These requirements must be met for the entire duration of the doctoral course which offers cutting-edge knowledge and in-company training experience for strengthening both the soft skills and employability of PhD candidates. According to the regional regulations, *Eureka* students must spend half of their time in the co-funding company whilst carrying out research activities at the university of enrolment. Furthermore, PhD candidates are exempted from paying any tuition fees. They only have to pay a regional tax for the right to study. The universities provide their students with a research budget on an annual basis. As emerged in previous works (e.g. Cardoso et al., 2019b; Heldal et al., 2021; Kihlander et al., 2011), since PhD students are co-overseen by a university and a firm supervisor, the research usually starts from challenges identified by the business organisation and reframed, together with the academic supervisor, in order to ensure research rigour and integrity and scientific quality. This means that *Eureka* can stimulate a cross-disciplinary and cross-sectoral approach (Fondazione CRUI, 2019).

As regards the firms participating in the IPP, as well as having at least one operating headquarter in the region, they should comply with at least one of the following

Table 1	Eurek	a programme: an o	verview			
Edition	Year	Co-funded schol- arships (number)	Eureka co-funding scheme	Scholarship approximate unitary cost (€)	Regional government co-funding (thousand $\boldsymbol{\varepsilon})$	PhD research project domains*
-	2012	60	Firm (1/3) Univ. (1/3) Gov. (1/3)	51,000	1360	Green economy, home automation, fashion, biotechnology, ship- building, tourism and cultural heritage
5	2013	87	Firm (1/3) Univ. (1/3) Gov. (1/3)	51,000	1717	Green economy, home automation, fashion, biotechnology, ship- building, tourism and cultural heritage
б	2014	70	Firm (1/3) Univ. (1/3) Gov. (1/3)	60,000	1400	Green economy, home automation, fashion, biotechnology, ship- building, tourism and cultural heritage
4	2015	68	Firm (1/3) Univ. (1/3) Gov. (1/3)	60,000	1574	Green economy, home automation, fashion, biotechnology, ship- building, tourism and cultural heritage
Ś	2016	50	Firm (1/5) Univ. (2/5) Gov. (2/5)	65,000	1534	Green economy, fashion, wooden-furniture, agri-food industry, tourism and cultural heritage, shipbuilding, mechanics, home automation, biotechnology, internationalisation, landscape and land conservation and promotion
6	2017	38	Firm (1/5) Univ. (2/5) Gov. (2/5)	65,000	1222	Manufacturing, wooden-furniture, Industry 4.0, construction and environmental energy, mechanics-mechatronics, innovative mate- rials, tourism, agri-food industry, blue economy, social services
٢	2018	27 16**	Firm (1/5) Univ. (2/5) Gov. (2/5)	70,000	861 1101***	Manufacturing, wooden-furniture, Industry 4.0, construction and environmental energy, mechanics-mechatronics, innovative mate- rials, tourism, agri-food industry, blue economy, social services
8	2019	21 20**	Firm (1/5) Univ. (2/5) Gov. (2/5)	70,000	690 1402***	Manufacturing, wooden-furniture, Industry 4.0, construction and environmental energy, mechanics-mechatronics, innovative mate- rials, tourism, agri-food industry, blue economy, social services
6	2020	22 20**	Firm (1/5) Univ. (2/5) Gov. (2/5)	70,000	684 1402***	Manufacturing, wooden-furniture, Industry 4.0, construction and environmental energy, mechanics-mechatronics, innovative mate- rials, tourism, agri-food industry, blue economy, social services, anti-seismic techniques and technologies
Total		499			€ 14,949	
Notes: ***co-1	*Resea	rch projects' doma from the regional g	ins have been jointly defined government for innovative do	d by the regional gov ctorates. Source: Autho	ernment and the four un ors' elaboration based on	iversities; ***number of scholarships for innovative doctorates; data gathered by the regional government of Le Marche

requirements: (i) have successfully participated in national and international research projects, (ii) have filed at least one patent in the last 5 years, and (iii) have an R&D department. A firm representative must contribute to defining the doctoral research project and to supervising the PhD student. Furthermore, firms must provide PhD students with specific training and support him/her in implementing the research project and provide access to laboratories, suitable working environments, scientific equipment, and to the data required in order to conduct research activities. It is worth noting that firms taking part in an IPP usually expect to develop new knowledge and to leverage on the opportunity of employing qualified human resources (Thune & Børing, 2015). For this reason, it is interesting to find out how many PhD candidates were, in the long run, hired or somehow retained in the local ecosystem of innovation. As well as the efficacy of an action, from the policy makers' perspective, this is also related to the professional trajectory of PhD graduates. PhD holders who subsequently move to work outside the region could be considered a partial failure of an IPP since the regional innovation system will not benefit from the knowledge and competences acquired by that PhD candidate.

Given the policy aim of favouring the innovation capabilities of firms, it would be better if talents were employed by firms in the Region, which would demonstrate the absorptive capacity of the companies involved. Thus, it would be interesting to investigate the average rate of PhD candidates relocating outside the region and whether this rate increases or decreases over time. It is also important to examine the factors affecting this rate, whether it is influenced by, for example, the size of the firms in question (hypothesising that smaller firms might have more difficulty retaining PhD graduates). If this hypothesis were to be verified, policy makers would, once again, face the usual dilemma: whether to choose larger firms with a higher absorptive capacity (picking winners) or support smaller firms and run the risk of 'losing' the people who have been trained there, on PhD programmes.

Also, 'reiteration' must be monitored, i.e. how many firms co-financed more than one scholarship in the period 2012–2020. From a policymaker's point of view, it is unclear how reiteration should be perceived. On the one hand, it may signal the efficacy of the IPP. On the other hand, given the limited number of resources, reiteration inevitably limits the number of firms that are able to access the programme. This is a common dilemma faced in industrial policy: the choice between picking the winners, those who best ensure the effective use of funds, or supporting 'disadvantaged' firms, thus accepting a higher risk of wasting public resources.

Starting from 2018, the regional government of Le Marche introduced a new type of IPP, namely, the *Innovative doctorate programme*. Specific goals were sought with this new IPP, amongst which were promoting cooperation between the universities in the Region; developing applied research projects that might benefit not only an individual firm but also a whole sector, or a cluster in the region, hence promoting cooperation between and amongst related firms; and encouraging cross-disciplinary and cross-sectoral research. This framework established that the PhD candidate would have 2 supervisors from different universities and scientific backgrounds and, also, must develop a research project in collaboration with two or more firms participating in one of the following regional clusters: Agrifood—Food Farming Innovation Cluster; e-living—Ambient Intelligence Innovation Cluster; Marche Manufacturing—Industrial Innovation Cluster; In Marche—Creativity Innovation Cluster (Fondazione CRUI, 2019). The first PhDs involved in this programme will graduate in 2024; thus, we are not able to include impact assessment for this action.

Descriptive statistics

Between 2012 and 2020, 499 PhD scholarships were funded: 443 within the *Eureka* IP and 56 within the *Innovative doctorate programme*. Until 2015, the number of scholarships was on average 71 per year, whilst between 2016 and 2020, the average was 42 scholarships per year. As regards the distribution of these scholarships, it is worth noting that 39% of them were co-funded by one university, the Polytechnic University of Marche. Instead, the other 3 higher education institutions, namely, the University of Camerino, the University of Macerata, and the University of Urbino co-financed, respectively, 23%, 22%, and 16% of the total number of scholarships.

The number of doctoral scholarships granted by each university also depends on the size of the university: the Polytechnic University of Marche is the largest in terms of students enrolled, and of academic and non-academic staff.² However, this figure is also influenced by the type of courses and research programmes offered by each university. IPPs are generally oriented more towards the scientific (science, technology, engineering, and mathematics, i.e. STEM) and the social science fields, rather than the humanities. The Polytechnic University of Marche, the University of Urbino, and the University of Camerino all have scientific or technology faculties/departments, whilst the University of Macerata is exclusively based on social sciences and humanities. Nevertheless, compared to the other universities, the number of PhD scholarships co-financed by the University of Macerata is relatively high.

Firms participating in the IPP were usually located within the same municipality as the University that was offering the PhD programme or in a nearby municipality (Fig. 1). More specifically, about 41% of the firms were in the province of the regional capital (Ancona) where the biggest university is located and about 36% of the companies were located in the province of Macerata. Firms based in the southern part of the region, i.e. the province of Fermo and the province of Ascoli Piceno, had more difficulty participating in this research programme: these provinces, respectively, contributed 8% and 5%, to the total number of scholarships.

As regards the economic sectors of the co-funding firms, Fig. 2 reveals that most of the companies, about 43%, operate in the manufacturing sector, which is the main sector in the region. Around 34% of the firms were active in the service sector, mainly related to professional, scientific, technical, administrative, and support service activities. Around 18% of the firms operated in the transport, storage, wholesale, and retail trade sector. With respect to firm size, it is important to note that only 1% of the companies were large enterprises, with sales above 1 billion Euro (Fig. 3), whilst 32% were small firms, i.e. with sales below 10 million Euro. Therefore, we can conclude that the IPP, as a type of investment in human capital formation, is transversal in terms of size of the firms.

Results and discussion

The case of Le Marche shows that the *Eureka* programme can contribute to strengthening the relationship between actors in the regional innovation ecosystem. Like other European IPPs (Bröchner & Sezer, 2020; Casano, 2015; Granata & Dochy, 2016), this

² According to the Ministry of University Research (MUR), the number of students enrolled in 2020 were: Polytechnic University of Marche 15,078, University of Urbino 14,894, University of Macerata 9901, and University of Camerino 6492 (Ufficio di Statistica settore Università e Ricerca http://ustat.miur.it/).

programme has been focused on work-based learning, leveraging on the interaction between basic and applied research and promoting co-creation of innovation at both product and/or process level.

As well as the participation of the regional government and of the 4 universities of the region, our analysis also revealed that there is a low level of concentration in terms of cofunding firms: during the 2012–2020 period, only about 13% of the PhD scholarships were co-financed by the same 10 firms (Table 2). Taking into account only the top 10 co-funding firms, it can be seen that these companies provided funding throughout the 9-year period in a regular manner. Furthermore, by dividing the period into three sub-periods (2012–2014, 2015–2017, and 2018–2020), we found that, except in one case, all these top firms had cofinanced at least one PhD scholarship in every sub-period.

Indeed, there was considerable involvement of firms in this IPP action. About 23% of the firms co-financed more than one PhD scholarship. About one-third concentrated their funding efforts for a relative short period of time, i.e. in the same 3-year sub-period, whilst 21% of them remained involved in the programme over the 9-year period by funding at least one PhD scholarship in each of the 3-year sub-periods. Considering both these findings and the characteristics of the firms involved in *Eureka*, our analysis confirms previous research which has revealed that the companies participating in IPPs are usually knowledge-intensive firms that have previously collaborated with universities and which already employ collaborators with postgraduate qualifications (Cardoso et al., 2019a; Thune, 2010).

The firms involved in *Eureka* operate in diverse sectors: manufacturing, services, health, and education. Over the years, such companies have co-funded applied research projects related not only to STEM but also to SSH disciplines, thus broadening the perspective of industrial doctorates (Karsten, 2020; Malm & Löfdahl, 2020). This empirical evidence supports previous works (e.g. Roolaht, 2015; Vitiello & Castelluccio, 2019) that argued—more generically—that there was a need to change the term 'industrial' or, rather, extend its meaning regarding these doctoral programmes as it is too narrow as it does not exclusively incorporate manufacturing industries and the domains of STEM. Furthermore, IPPs are becoming more cross-disciplinary, and cross-sectoral, as they contribute to the development of products and services that might be useful to and for a wide variety of economic fields, consumers, and users (Vitiello & Castelluccio, 2019).

The analysis also shows that firms participating in the IPP were mostly located either within the same municipality as the university that was co-financing the scholarship, or in a nearby municipality. Both geographical proximity to a university, and established relationships with local firms, play an important role in promoting and implementing these IPPs which require frequent interactions between the actors involved. This evidence confirms previous research that stressed the importance of physical proximity since the PhD student must work both at the university and in the firm (Danish Ministry of Higher Education & Science, 2017). The proximity of these locations makes the fulfilment of both academic and business tasks much easier. Wallgren and Dahlgren (2007) demonstrated that the closer the physical proximity of the academic and the firm's supervisors is to the PhD candidate, the higher will be both the quality of the supervision and the level of the student's participation in the training programme.

Furthermore, our findings advance knowledge about the phenomenon of university satellite campuses, also known as peripheral or regional campuses, which have been expanding in Italy since 2000 (Seri & Compagnucci, 2024). It is worth noting that companies based in the southern part of Le Marche, namely, the province of Fermo and the province of Ascoli Piceno, encountered more difficulty participating in *Eureka*. In these NUTS-3



Fig. 1 Geographical distribution (in quintiles) of co-funding firms by municipalities (2012–2020). *Notes:* the figures in parentheses denote the quintiles and the number of firms in the quintiles. Darker areas represent higher values. *Source:* Authors' elaboration



Fig. 2 Distribution of co-funding firms by sector of economic activities (2012–2020). *Notes*: ATECO sections are in parenthesis. ATECO code is the Italian national version of the European classification of economic activities Nace Rev. 2. *Source*: Authors' elaboration



Fig. 3 Distribution of co-funding firms by sales (2012–2020). *Source*: Authors' elaboration based on AIDA Bureau Van Dijk data

regions,³ the four universities have established small satellite campuses, which latter are traditionally more oriented toward offering teaching services at undergraduate level, rather than performing applied research in collaboration with firms.

As regards the geographical location of the employers of PhD graduates, data show that 62% were located in Le Marche. If we consider regional universities, the percentage of PhD graduates employed rose to 76%. Indeed, 39% of PhD graduates have some form of post-graduate temporary contract, such as a research contract and a post-doctoral position, in one of the 4 regional universities. Similar percentages can be seen in many other Italian universities (AlmaLaurea, 2024) and in EU countries such as Austria (Geppert et al., 2024). This means that about 1 out of 4 PhD holders was, at the time of the data collection, employed in firms located in other Italian regions, whilst about 11% of them were working in firms located abroad. Although *Eureka* has achieved a high talent retention rate within the regional innovation system, the programme has not been entirely successful in achieving the target that is usually sought by policymakers implementing IPPs, regarding strengthening employment in private sectors of strategic importance for their regions (Amaral & Carvalho, 2020).

Figure 4 shows that the majority (74%) of PhD holders were employed in the province of Ancona and Macerata, which are the two NUTS-3 regions with the highest share of funding firms. However, analysis of the economic sector of the firms where PhD holders were being employed demonstrates that in most cases, the knowledge and skills acquired were, in the end, capitalised in different sectors (Fig. 5): indeed, 63% of the PhD graduates found employment in the 'Education and in Other services sector'. More specifically, 24%

³ The nomenclature of territorial units for statistics (*Nomenclature des Unités territoriales statistiques – NUTS*) is a geographical system, according to which the territory of the European Union is divided into hierarchical levels. The three hierarchical levels are known as NUTS-1, NUTS-2, and NUTS-3. This classification enables cross-border statistical comparisons at various regional levels within the EU. In many cases, the classification ties in with the administrative structure of the Member States. In Italy, NUTS-3 regions have a population of between 150,000 and 600,000 and districts known as provinces. In the case of Le Marche, the most populated NUTS-3 region is the province of Ancona with about 460,000 inhabitants, while Fermo is the least populated with about 170,000 inhabitants.

Co-funding firms	PhD scholarship		PhD programme between:		
	Number	%	2012-2014	2015-2017	2018-2020
Loccioni	20	4.5%	19	1	0
iGuzzini illuminazione spa	9	2.0%	4	4	1
GROTTINI LAB srl	6	1.4%	2	2	2
DIASEN srl	5	1.1%	1	3	1
CONTRAM spa	5	1.1%	2	2	1
Magazzini Gabrielli spa	5	1.1%	1	2	2
Nuova Simonelli spa	4	0.9%	1	2	1
Filippetti spa	4	0.9%	1	2	1
Progetto costruzione qualità PCQ srl	4	0.9%	2	2	0
PlayMarche srl	4	0.9%	1	1	2
Total		13.2%			

 Table 2
 Top 10 co-funding firms involved in Eureka (2012–2020)

Source: Authors' elaboration

were employed in firms operating in the 'Other services sector' which includes both the professional, scientific, and technical activities sector (13% of the cases) and the information and communication services sector (8%), and 39% of PhD holders were working in the four universities that had participated in the IPP. This latter percentage is higher compared to the general average for Italy where recent data from AlmaLaurea (2024)⁴ have revealed that about 31% of PhD holders have a post-doc position at an Italian university. This could suggest that compared to their colleagues, PhD candidates who have graduated in one of the universities located in Le Marche are less keen to move to universities located in other regions. It is also worth noting that about 23% of industrial PhD graduates were employed in the manufacturing sector; and about 13% in the wholesale, retail trade, transport, and storage industry (Fig. 5).

Empirical evidence also shows that only 6% of PhD holders were working in the firm that had co-financed their PhD scholarship. However, it should be noted that this percentage does not correlate with firm size. Indeed, about half of these firms were very small firms, i.e. with sales up to 4.99 million Euro, and the other half were small or medium-sized firms, i.e. with sales between 10 and 999 million Euro. However, these firms were top co-funding companies.

Conclusion, policy implications, and avenues for future research

Educational policies play a crucial role as a means of implementing industrial policies for structural change in geographical areas, by nurturing talents and involving them in innovation ecosystems (Bianchi & Labory, 2016; Greenwald & Stiglitz, 2013). This paper has examined the case of the educational policy developed by one regional government, in cooperation with local universities, to support structural change in their innovation

⁴ Almalaurea is a public funded institution in Italy which publishes an annual survey of the profiles and employment status of Italian graduates and PhD holders.

ecosystem. The focus has been on the use of an IPP to achieve some strategic long-term goals, in concert with Smart Specialization Strategies (Bernhard & Olsson, 2023). Our study offers a retrospective long-term overview of the nine editions of the *Eureka* IPP, carried out in Le Marche (Italy) between 2012 and 2020, co-funded by the regional government, the 4 universities in the region and 243 local firms. The descriptive analysis offers a general picture of the impact and magnitude of the policy implemented from a triple helix perspective, not only in terms of PhD holders' employment but also with reference to the characteristics of the participating firms.

Successful and less successful aspects of *Eureka* have been identified and described in the previous sections, which, hopefully, will contribute to the academic and policy debate about the role of IPPs. The policy adopted by the regional government has only partially bridged some of the gaps in the local innovation ecosystem; thus, future actions should find a way to support IPPs in a more effective manner. This paper has examined the potential, the efficacy, and the limits of the IPP to (1) improve cooperation of actors within the innovation ecosystem and (2) train and retain talents in the region.

Cooperation of actors of the innovation ecosystem

Opening doctoral programmes to cooperation with diverse local actors can encourage cross-disciplinary and cross-sectoral research, sharing and reducing both the costs and the risks related to innovation-driven paths. Boundaries between the actors of the innovation ecosystem are diminished and knowledge transfer or co-creation improve dramatically. This is especially important in geographical areas, such as Le Marche, with many SMEs



Fig.4 Geographical distribution (in quintiles) of co-funding firms, by municipalities, where PhD candidates were employed (2012–2020). *Notes:* the figures in parentheses denote the quintiles and the number of firms in the quintiles. Darker areas represent higher values. *Source:* Authors' elaboration



Fig.5 Distribution of firms where PhD candidates were employed by economic sector (2012–2020). *Source:* Authors' elaboration

that often have less capacity for innovation and tend to ignore the benefit of cooperation with academics for product and process innovation. Alignment of applied research activities of universities to Smart Specialization Strategies of the Region is also encouraged, thanks to policy priorities embedded in IPP calls.

Furthermore, the geographical proximity of the firm to the university is crucial. Our analysis has shown that implementing co-financed PhD scholarships is easier for firms located near the university because of the need for frequent interactions. On the other hand, to overcome the issue of geographical distance, local (and central) government and universities should promote campaigns to motivate potentially interested firms by providing clear information about the benefits deriving from university-industry cooperation. Coordination mechanisms could be implemented to allow constant monitoring and alignment between universities and firms.

Talent retention

Although doctoral knowledge has sometimes been regarded as 'a luxury' or 'superfluous', with some firms preferring lower-grade skills (Herman, 2013, p. 271), our analysis suggests that *Eureka* may be considered generally successful in promoting the employment of PhD holders as well as strengthening university-industry interactions. Indeed, the programme has mobilised about 500 PhD candidates who have been involved in applied research activities jointly defined by the firm and the academic supervisors.

When considering the retention of PhD holders in Le Marche, the IPP has proved relatively successful. About 75% of the PhD graduates found employment in the region which has neither big companies nor big cities (usually more attractive to highly educated people). This rate of retention is also reflected in the high percentage of PhD graduates (39%) who found a post-doc position in one of the four universities where they were enrolled. Although this percentage is higher than the Italian average for PhD holders, *Eureka* has been less successful in increasing the employment of PhDs in the firms that co-financed the IPP. Only 6% of the PhD holders have been hired by the firm that co-financed their scholarship: thus, there has been only a slight increase in the number of highly educated workers absorbed by firms at the local level.

The size of a firm is also important for talent retention. Policy makers face the dilemma of whether to co-fund PhD scholarships in larger firms with higher absorptive capacity (picking winners) or co-financing doctoral projects in smaller firms. Whilst the latter need support for strengthening their R&D activities, they also are at greater risk of 'losing' PhDs, trained within the IPP, due to their lower capacity to retain young talents. Thus, it is crucial to plan and implement measures to help SMEs hire PhD holders and to actively involve them in business activities. Amongst several potential policy tools, it might be useful to adopt fiscal incentives and flexible contracts.

Avenues for future research

Future research should extend our analysis by identifying and measuring the diverse impacts which have been exerted by the IPP policy at various levels: the labour market, firms, human capital formation and retention, and be used when shaping future policies. Further analysis could also provide a comparison between industrial and 'traditional' PhD holders with respect to time of first employment, current sector of employment, professional position, and salary level. Moreover, it would be interesting to examine the inflow and outflow of PhDs within different regional innovation ecosystems. Along with the need for quantitative longitudinal studies (Compagnucci & Spigarelli, 2024), qualitative analyses could make it possible to gain further insights into the distinctive perspectives and motivations of firms participating in IPPs (Assbring & Nuur, 2017; Bernhard & Olsson, 2020; Grimm, 2018). Furthermore, it would be interesting to explore whether, and how, IPPs affect innovation performance at the regional level, as well as investigating to what extent such programmes are contributing, or could contribute, to enhancing the synergies between education and innovation policies (Marinelli et al., 2018). To this end, future research should seek to reveal the collaborative potential between academic disciplines, i.e. STEM and SSH, in relation to PhD research projects, and the economic sectors of the funding firms. A final point that deserves attention is the ability of IPPs to open local innovation ecosystem to the global network of knowledge (Marginson, 2024), boosting connections with foreign universities and firms whilst creating international linkages for knowledge sharing.

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Declarations

Competing interests The authors declare no competing interests.

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