Universidade do Minho
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Innovation and Productivity: Impact assessment of copromotion projects

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STATEMENT OF INTEGRITY

I hereby declare having conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results along the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Resumo

Esta dissertação descreve, analisa e avalia os impactos dos projetos em copromoção, subsidiados por Fundos Europeus em Portugal, entre 2006 e 2019, relativos aos Quadros Financeiros Plurianuais QREN e PT2020. O objetivo é, com recurso a dados em painel, avaliar econometricamente, através de um modelo de efeitos fixos, os impactos dos projetos em copromoção no desempenho das empresas, comparando-os com projetos individuais de I&D e avaliar de que forma as características dos consórcios afetam os resultados esperados.

O investimento em I&D é fundamental para o crescimento económico. No entanto, a existência de falhas de mercado pode conduzir a uma situação de subinvestimento e, consequentemente, a taxas de crescimento económico subóptimas. Dado que o desenvolvimento de projetos em copromoção pode ajudar as empresas a superar falhas de mercado, as políticas públicas têm vindo a apostar na formação destas parcerias. Todavia, não há consenso sobre os efeitos destas iniciativas no desempenho das empresas, com os impactos a variar dependendo das características dos consórcios.

Os resultados desta dissertação sugerem que os projetos de I&D em copromoção têm efeitos positivos na produtividade das empresas, principalmente nas micro e pequenas empresas, e que superam os benefícios dos projetos individuais. No entanto, para o nível de vendas e das exportações, os projetos individuais parecem ter vantagem, sendo os efeitos ao nível do emprego semelhantes. Os impactos nas pequenas empresas parecem ser sensíveis às características do consórcio em que desenvolvem o projeto de I&D. Em suma, um número mais elevado de parceiros diminui os benefícios do projeto para todos os tipos de empresas, com mais intensidade para as menores, e os ganhos de produtividade das empresas mais pequenas são reduzidos nas parcerias com entidades mais produtivas. Contrariamente, as grandes empresas, ao nível das exportações, beneficiam mais ao fazerem parcerias com empresas maiores e mais exportadoras.

Palavras-chave: fundos europeus; I&D; produtividade; projetos em copromoção.

Abstract

This dissertation describes, analyses, and evaluates the impacts of projects in copromotion, subsidised by European Funds in Portugal, from 2006 to 2019, related to the Multiannual Financial Frameworks QREN and PT2020. The objective is, using panel data, to econometrically evaluate, through a fixed-effects model, the impacts of copromotion projects on firms' performance, comparing them with individual R&D projects, and assess how the characteristics of the consortiums affect the expected results.

Investment in R&D is essential for economic growth. However, market failures can lead to underinvestment and, consequently, to suboptimal economic growth rates. Given that copromotion projects can help firms overcome market failures, public policies have focused on forming these partnerships. However, there is no consensus on the effects of these initiatives on the performance of firms, with the impacts varying with the characteristics of the consortiums.

The results of this dissertation suggest that R&D copromotion projects have positive effects on the productivity of firms, especially in micro and small firms, and that they outweigh the benefits of individual projects. However, for the level of sales and exports, individual projects seem to have an advantage, with similar employment effects. The impacts on small firms seem to be sensitive to the characteristics of the consortium in which they develop the R&D project. In short, a higher number of partners reduces the project's benefits for all types of firms, more intensely for the smaller ones, and the productivity gains of smaller firms are reduced in partnerships with more productive entities. In contrast, in terms of exports, large firms benefit more from partnering with larger and more exporting firms.

Keywords: copromotion projects; European funds; productivity; R&D.

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List of Acronyms

ANI - Agência Nacional de Inovação

ERDF - European Regional Development Fund

HEI - Higher education institutions

NSRF - National Strategic Reference Framework

OECD - Organisation for Economic Co-operation and Development

PT2020 - Partnership Agreement

R&D - Research and Development

R&I - Research and Innovation

R&TD – Research and technological development

SI I&DT - System of Incentives for Research and Technology Development

SI Innovation - System of Incentives for Innovation

SI Qualification - System of Incentives for Qualification

SMEs - Small and medium-sized enterprises

STS - Scientific and Technological System

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1 Introduction

Investment in R&D (Research and Development) is fundamental as a driver of competitiveness, productivity, and economic growth (Romer, 1990; Aghion and Howitt, 1998; Bayona-Sáez & García-Marco, 2010; Bellucci et al., 2016; Cin et al., 2017). However, due to market failures, the socially desirable level of innovation is not equal to the equilibrium level of the markets, providing a rationale for public subsidies (Bloom et al., 2019; Bryan and Williams, 2021; Teichgraeber & Van Reenen, 2022).

R&D investments are uncertain and associated with a higher risk of failure (Feldman & Kelley, 2003; Bayona-Sáez & García-Marco, 2010). Additionally, micro-sized firms, SMEs (small and medium-sized enterprises) and new entrants have financial constraints for these types of investments due to asymmetric information and a higher risk of default (Fazzari et al., 1988; Beck and Demirguc-Kunt, 2006; Freel, 2007; Alessandrini et al., 2010; Czarnitzki & Hottenrott, 2011; Cin et al., 2017). Moreover, R&D is a non-rival good (its use by a firm will not prevent its use by others), and so it may lead to potential knowledge spillovers where other firms will benefit from others' innovation efforts (Katz, 1986; Feldman & Kelley, 2003; Belderbos et al., 2004; Crespi et al., 2020), worsening the underinvestment problem.

To overcome these market failures, governments intervene in the market by issuing policies to incentivise the socially desirable investment in R&D and promote the consequent spillovers, hoping that it will create positive externalities for the rest of the economy (Grossman and Helpman, 1991; Aghion and Howitt, 1990; Aguiar & Gagnepain, 2017; Cin et al., 2017). Policies aimed to support R&D are seen as crucial for regional development, with the OECD Innovation Strategy (OECD., 2010) recognising the role of innovative policies in sustaining innovation-induced productivity. The European Union has also acknowledged R&D as one of its priorities (De Blasio et al., 2015). It has launched a series of programs whose goal is to raise the productivity and competitiveness of European firms through R&D (Teichgraeber & Van Reenen, 2022).

However, public intervention in these activities is not a consensual solution, being the main arguments against it the following: it has a substitution effect rather than a complementary one; the possibility of negligence regarding public money, which would not happen if the funds were private; the increase in R&D costs; and even the chance of the government being inefficient on the allocation of resources among the research fields (Bayona-Sáez & García-Marco, 2010).

The biggest concern about the efficacy of public subsidies lies in the answer to the question: What would be the behaviour of the firms if they had not received the grants? The possibility of a crowding-out effect, that is, of the subsidy acting as a substitute for private investment, leads to situations where

projects that are being financed by public resources would be carried out even without the awarded incentives (Brown et al., 1995; Wallsten, 2000; Barajas et al., 2012). This crowding-out phenomenon happens because public capital presents a lower cost to every firm. However, the literature is not unanimous in recognising the presence of this effect (De Blasio et al., 2015; Cin et al., 2017).

Several authors find evidence pointing out the crowding-out problem (Wallsten, 2000; Sissoko, 2011; De Blasio et al., 2015), but other studies do not perceive any signs of this phenomenon (Feldman & Kelley, 2003; Duguet, 2004; González et al., 2005; González & Pazó, 2008; Santos, 2019) and there is even evidence of a partial-effect (Czarnitzki & Lopes-Bento, 2013). For instance, findings show that it occurs more in larger firms, whilst small ones carry out projects they couldn't without public support (Pavitt, 1998; Lach, 2002; Görg & Strobl, 2007).

Concerning the policy toolkit to increase research and innovation, Tether (2002) considers that cooperation between firms and between firms and the scientific and technological system is a way of overcoming several restrictions to R&D, namely: the inherent risk of innovation; financial constraints; bureaucratic obstacles; and lack of market/technologies/customers information. R&D collaborations have been increasing recently and are now an essential component of the innovation process (Tether, 2002; Aschhoff & Schmidt, 2008). R&D collaborations may be beneficial to the economy as a whole by diminishing the costs of innovation and spreading knowledge more efficiently and effectively through internal and voluntary spillovers (Katz, 1986; Combs & Link, 2003; Bellucci et al., 2016)[1].

The European Union has explicitly encouraged the formation of partnerships in R&D projects (Aschhoff & Schmidt, 2008; Amoroso et al., 2018). In the early 1980s, European policies aimed to promote research partnerships to support the technology sectors and their international competitiveness. Since then, the policies have been upgraded, with financial raises, better coordination, and a more central role in industry-university collaborations (Aguiar & Gagnepain, 2017 ¸ Galán-Muros et al., 2017).

In Portugal, R&D partnerships have been supported by the government with European Funds in the last two multiannual financial frameworks (NSRF - National Strategic Reference Framework; and PT2020 - Partnership Agreement) within the scope of the System of Incentives for Research and Technology Development (SI I&DT) to increase the investment in R&I (Research and Innovation) and enhance firm's competitivity.

[1] According to Crespi et al. (2020), research collaborations are the preferable way to produce spillovers.

In Portugal, projects in copromotion are classified as such when performed in partnerships between firms or firms and entities of the scientific and technological system, to promote the development of R&D activities through the complementarity of competencies or shared interests, leading to the potentiation of synergies, cost, and risk-sharing.

Since public resources finance these projects, assessing their impacts on the economy is relevant. This study will look to deepen the study of Alexandre (2021), who, for the first time, explored the effects of copromotion projects on the performance of Portuguese firms. The research questions of the present study are:

1) What are the impacts of R&D copromotion projects on firm performance, and how do they compare to the effects of individual projects?
2) How does the composition of the consortium affect the impacts on firm performance?

The second research question evaluates the consortium from two perspectives: the number of members and possible coordination problems; and from a perspective of possible knowledge transfer from larger firms to smaller ones. To the best of our knowledge, this study, in addition to measuring the effects of R&D projects on firm performance, will be the first to evaluate the possible existence of diffusion spillovers and the impact of the consortium composition in Portuguese R&D joint ventures.

To answer the proposed questions, this work will use 3 distinct datasets, provided by COMPETE, Agência Nacional de Inovação (ANI), and Banco de Portugal. The first two entities provided relevant information regarding the copromotion projects in Portugal, while the latter gave very rich firm-level information. By merging the three databases, it became possible to construct a panel dataset from 2006 to 2019 and use it to answer the research questions through a fixed-effects approach.

The estimations later presented in this dissertation indicate more benefits related to participating in copromotion projects for smaller firms. Comparing this modality with the individual projects for R&D, the firsts are only more beneficial in productivity terms. In contrast, individual projects offer more positive effects on sales and exports (both modalities similarly influence employment). When considering the characteristics of the consortium, they seem to be more relevant for smaller firms. More members within the partnership harm the outcomes, particularly for small firms. The more significant the difference to the most productive firm within the consortium, the smaller the productivity gains will be. These findings suggest that micro and small Portuguese firms are the primary beneficiaries of copromotion projects. Still, the benefits seem to hinge on the composition of the consortium they belong to.

The remainder of the dissertation is structured as follows. Section 2 presents a review of the literature on subsidies for R&D. Section 3 describes the data while giving an overview of the copromotion projects undertaken in Portugal and an evaluation of how some firm characteristics affect their applications and approval processes. Section 4 presents the empirical strategy and discusses the results. Section 5 concludes with some final remarks.

2 Literature Review

As mentioned in the introduction, projects in copromotion may be an excellent strategy to overcome some market failures connected to investment in R&D. Firms tend to engage in copromotion projects to reduce the risks associated with innovation; share costs; avoid wasteful duplications of research; overcome financial obstacles and constraints; and look for external resources (being them monetary or knowledge-based) otherwise unreachable (Katz, 1986; Tether, 2002; Feldman & Kelley, 2003; Barajas et al., 2012; Alexandre et al., 2021).

Although projects in copromotion may mitigate underinvestment in R&D, they also entail additional costs. Entities participating in such undertakings are susceptible to increased management costs, problems of free-riding, or time to build up the needed trust in the partner (Benfratello & Sembenelli, 2002; Feldman & Kelley, 2003; Barajas et al., 2012; Crespi et al., 2020). On the other hand, some of the potential spillovers are only achievable through intangibles. Thus, it requires networks with an excellent organisation to transfer knowledge from one organisation to another. Hence, the externalities may be compromised by coordination failures. Therefore, coordination is vital in copromotion projects, and firms will only engage in a partnership when the expected gains outweigh the costs (Aschhoff & Schmidt, 2008; Crespi et al., 2020).

Those results suggest that participation in research collaborations is not random and depends on numerous variables. Several studies report that larger firms are associated with a higher probability of being awarded incentives, as well as having higher performances and production capacity in terms of wages per employee, tangible fixed assets, or being located within a high-intensity export region (see, for example, Tether, 2002; Feldman & Kelley, 2003; Bayona-Sáez & García-Marco, 2010; Hud and Hussinger, 2015; Aguiar & Gagnepain, 2017; Santos, 2019). On this matter, large-sized firms benefit from being more capable of bearing the fixed costs associated with R&D projects; they meet the bureaucratic demands of the application more easily (Blanes & Busom, 2004; Czarnitzki & Hussinger, 2004) and also have the additional incentive to participate so they can monitor the latest innovations (Aguiar & Gagnepain, 2017). However, some evidence state that larger firms are less willing to participate and apply for joint ventures, to not share knowledge with their smaller competitors (Röller et al., 2007; Barajas et al., 2012).

Blanes & Busom (2004) and Aguiar & Gagnepain (2017) argue that government institutions may also prefer large-sized firms, as they have associated higher rates of success regarding R&D. This practice of the government is acknowledged as picking the winner's approach, that is, supporting projects with a

higher associated rate of success. Firms with past experiences with public funding (including rejected firms) take advantage of their application knowledge to apply for future calls with better submissions (Barajas et al., 2012).

Hud and Hussinger (2015) also found that younger firms have better chances of getting their projects approved as they are more prone to innovate (Czarnitzki and Lopes-Bento, 2013), while Feldman & Kelley (2003) argue that riskier projects and new partnerships are more prone to be approved.

Regarding the constitution of the partnerships and their probability of getting support, projects with participants already embedded in research networks and more prone to diffuse their knowledge tend to be favoured, as they present a higher expected return in terms of new knowledge and spillovers (Feldman & Kelley, 2003). In this sense, the same author states that the participation in projects in copromotion, with either other firms or universities, allows the participants to be part of networks with other agents of the innovation system and to enjoy spillovers from other applicants in the future. However, other scholars warn that firms engaging with higher education institutions tend to be larger, as they are more aware of their innovative capabilities, have more absorptive capacity, and have the resources needed to withhold the partnerships (Tether, 2002; Freitas et al., 2013).

Some authors have pointed out that cultural and cognitive differences between universities and firms are barriers to the existence of more partnerships, yet they also emphasise how industry-university collaboration projects are a way to solve conflicts that may arise as a result of those differences (Lee, 2000; Lam, 2011). OECD also supports higher proximity between innovative institutions and industry to facilitate knowledge and technology transfers, stating that the current relationships need to improve (e.g., OECD, 2010).

For the actual effects arising from R&D research, there is evidence stating that the knowledge spillovers produced lead to improvements in productivity (Basant & Fikkert, 1996; Coe & Helpman, 1995; Adams & Jaffe, 1996; Sissoko, 2011; Cin et al., 2017; Crespi et al., 2020). Cin et al. (2017) proposed some explanations found in the literature for the productivity increments detected, such as "cost-sharing, risk sharing, and the inducement of external investment through the provision of qualitative information to investors to facilitate decision making". In its study regarding Korean SMEs and the impact of R&D on their performance, between 2000 and 2007, Cin et al. (2017) noticed gains among the treated and the untreated firms that were geographically close. Crespi et al. (2020), in an analysis regarding R&D grants for firms in Chile, conclude that those effects are not linear, and a significant mass of treated firms is needed to produce spillovers. On the other hand, according to Crespi et al. (2020), programs that are too

large may generate a business-stealing effect instead of a positive externality, so there are saturation points that need to be considered in the policy design.

Several authors have concluded that copromotion projects positively impact productivity growth (e.g., Benfratello & Sembenelli, 2002; Belderbos et al., 2004; Aguiar & Gagnepain, 2017). However, those impacts are dependent on firms' characteristics: the magnitude of the effect decreases for more productive firms (Benfratello & Sembenelli, 2002; Sissoko, 2011); on the other hand, firms that partner with foreign multinationals present more gains (Belderbos et al., 2004).

However, the literature is not unanimous on the impact of copromotion projects on firms' productivity. Cannone & Ugheto (2014), when evaluating public support for R&D in Italy, found no evidence of any other impact of joint ventures on productivity. Barajas et al. (2012), even though they also did not discover any direct effect of being part of joint ventures on labour productivity, found an indirect effect through intangible fixed assets by employee that will generate productivity growth. Subsidised firms may present inefficiencies regarding productivity levels since employment increases positively affect the decision to award the funds. For that reason, as found by Bernini & Pellegrini (2011), firms tend to commit to employment levels above their optimal level to receive the funds, which ultimately will negatively impact their productivity. Santos (2019) corroborates that result as it found that, due to that phenomenon, non-subsidized firms in Portugal increased their labour productivity more when compared with the awarded firms. Moreover, some studies find that private R&D leads to higher returns when compared to publicly funded R&D (Griliches & Lichtenberg, 1984; Lichtenberg & Siegel, 1991), and those projects perform better results concerning productivity as well (Billings et al., 2004).

Additionally, supports for investment in R&D and research partnerships are not limited to productivity effects. Innovation is also considered a driver of employment (OECD, 2010), with Bellucci et al. (2016) and Santos (2019) concluding that subsidised firms employ more people than the non-treated ones. However, to reflect the lack of consensus within the literature, Sissoko (2011) cannot find consistent evidence on the relationship between R&D subsidies and employment.

In general, R&D subsidies lead to an increase in investment and innovation levels (see, for example, Feldman & Kelley, 2003; Cannone & Ughetto, 2014; Bronzini & Iachini, 2014; Bellucci et al., 2016; Cin et al., 2017; Santos, 2019; Crespi et al., 2020). However, those increments in private R&D investments are not synonymous with positive effects on productivity or economic growth (Hall & Maffiolo, 2008). On the other hand, some authors also find that R&D subsidies do not lead to the increment of investment in R&D (De Blasio et al., 2015), with Bronzini & Iachini (2014) arguing that, even though small firms indeed

increase their investment level due to the awarded subsidies, no evidence supports the same impact for large firms.

There is a wide range of studies supporting that subsidies to small-sized firms result in more benefits compared with the ones registered for larger firms, along several dimensions (Busom, 2000; Lach, 2002; Hyytinen & Toivanen, 2005; Lööf & Heshmati, 2005; González & Pazó, 2008; Bronzini & Iachini, 2014). The logic behind those differences relates to smaller firms' previously mentioned financial constraints. With the attribution of R&D subsidies, the government successfully reduces those constraints, leading small firms to undertake projects they would not otherwise (Criscuolo et al., 2019).

Bellucci et al. (2016), when comparing the effects of copromotion projects with the impacts of individual undertakings on Italian SMEs between 2003 and 2012, found that public subsidies for research in copromotion projects are less effective than the resources allocated to individual research projects. According to the results of those authors, individual projects present apparent effects on investments and employment. In contrast, copromotion projects showed weaker and mixed effects, such as lower growth in employment and a negative impact on investment. Crespi et al. (2020) also compared individual and joint research projects in Chile and concluded that the benefits are broadly similar. Bellucci et al. (2016) warn of the possible presence of free-riding, moral hazard, and selection drawbacks in 'imposed' partnerships that need to be accounted for in designing public policies that may affect the final impacts.

The literature has been quite unanimous that these effects of R&D partnerships will differ depending on the type of cooperation and partners (Belderbos et al., 2004). There is evidence that more market-oriented partnerships lead to a higher probability of better economic effects among the participants. Benfratello & Sembenelli (2002) and Bayona-Sáez & García-Marco (2010) analysed the Eureka program, which promotes R&D partnerships with a more market-oriented purpose and found positive effects of the projects on firms' profitability one year past the completion of the venture and a significant impact on labour productivity.

Concerning the characteristics of the partnerships, consortiums with suppliers look for cost reductions by assuring the quality and improvements on the inputs. In contrast, partnerships with competitors are more prone to generate incremental innovations and increase productivity through cost-sharing (Belderbos et al., 2004). Aschhoff & Schmidt (2008) add that collaborations between competitors and firms within the same sector achieve cost reductions as they significantly impact the production process. However, these collaborations may raise anti-competitive behaviours (Tether, 2002). Partnerships with customers increase the chances of acceptance by the market, as firms are more aware of their

preferences, which is even more relevant when considering novel products that are being newly introduced to the market (Belderbos et al., 2004). These partnerships with other industry actors lead to research on more marketable knowledge (Aguiar & Gagnepain, 2017).

We expect that partnerships between firms involving small and large firms have a higher potential for innovation diffusion and, thus, for generating positive externalities for smaller-sized firms. These arrangements have been increasing through the years (Alvarez & Barney, 2001; Rothkegel et al., 2006), but their pursuit is often problematic, facing trust-based issues, lack of cooperation, and opportunistic behaviours (Das & Teng, 1998; Hancké, 1998). According to Sawers et al. (2008), there is a significant vulnerability concern from SMEs about large-sized firms regarding the possibility of knowledge appropriation. Some authors report cases of firms felting exploited and facing bankruptcy upon the end of partnerships with large firms (Alvarez & Barney, 2001). On the other hand, Rothkegel et al. (2006), with the support of other authors, recognises the possibility of success of this type of partnership when they are based on trust and compatible goals (see, for example, Ring & Van de Ven, 1994; Child, 2001).

Concerning partnerships with institutions from the scientific field, several studies present evidence of a positive effect of relationships with universities and research centres on the sales volume arising from the creation of new products (Lööf & Heshmati, 2002; Belderbos et al., 2004; Aschhoff & Schmidt, 2008; Lööf & Broström, 2008). The new products enable firms to enter new and different markets or market segments. Moreover, firms allying themselves with universities and other research entities may benefit from economies of scale, incremental knowledge, more technical expertise, and impactful findings (Feldman & Kelley, 2003; Argyres & Silverman, 2004). D'Este & Perkmann (2011) emphasise the possible conflict of interests, where universities are more oriented to basic research while firms primarily intend to commercialise their research output. Yet, to Belderbos et al. (2004), the role of universities, and competitors, to some extent, on projects in copromotion, are essential to generate radical innovations and novel products for the market. Also, partnerships with universities are associated with productivity gains due to more effective public spillovers (Belderbos et al., 2004).

Recent evidence suggests that SMEs benefit more than larger firms from collaborations with universities (García-Vega & Vicente-Chirivella, 2020; Spanos, 2021), though most of the partnerships formed with universities are composed by large firms (Alexandre et al., 2021). Motohashi (2005) states that large firms look primarily for R&D collaborations while SMEs only engage in research partnerships during the final product stage. Until then, their preference lies in technical consulting. Freitas et al. (2013) explain this phenomenon to the fact that small-sized firms prefer more personal contacts with university

academics, while, conversely, larger firms look for more institutional partnerships, with departments or even TTOs, for instance, which are easier to process for the higher education institutions (see, also on this issue, Alexandre et al., 2021).

The referred TTOs are considered one type of intermediary institution, which have a central role in the innovation system and diffusion of knowledge. They bridge the existent gaps between academia and industry; consequently, their optimisation has become a crucial guideline in technology policy (Wright et al., 2008; Alexandre et al., 2021). They also aim to reduce the transfer costs for firms, ensure that agents have conditions of appropriability, and foster trust between them (Etzkowitz & Klofsten, 2005; De Wit-de Vries et al., 2019).

The current findings support the conclusions that these institutions are essential to building trust, particularly for SMEs, who face more barriers regarding knowledge acquisition, helping in the process of overcoming those barriers between them and universities, being considered effective in their purpose of transferring knowledge, yet, the literature is still scarce on this topic (Giarreta, 2014; Fernández-Esquinas et al., 2016; Villani et al., 2017; Alexandre et al., 2021).

3 Copromotion projects in NSRF and PT2020

As referred previously, projects in copromotion are a tool granted in the frameworks approved by the Portuguese republic and funded by European funds, namely through the ERDF (European Regional Development Fund). The frameworks in study are the NSRF, which regulated the use of the community funds between 2007 and 2013, and the PT2020 in 2014-2021. Each program includes three distinct systems of incentives for three specific areas: SI Qualification, SI Innovation, and SI I&DT. Projects in copromotion are a modality funded by SI I&DT.

The main goal of the SI I&DT is to increase the investment in R&I and enhance firm's competitiveness by promoting partnerships between them and entities from the STS (Scientific and Technological System), growing knowledge-intensive activities, creating value based on innovation, developing new products and services (especially in activities of greater technological and knowledge intensity) and increase national participation in international R&I programs and initiatives (Ordinance No. 1462/2007; Ordinance No. 57-A/2015).

During NSRF, projects in copromotion were a modality that only included R&TD firm projects. For PT2020, the modality of copromotion projects comprises five typologies: R&D firms projects; demonstration projects; industrial property protection; internationalisation of R&D; and mobilising programs. Within these typologies, firms would choose which modality they would like to apply, be it with individual or copromotion projects (the mobilising programs were the unique type that required appliances in copromotion).

3.1 Data

The dataset used to study the copromotion projects undertaken in Portugal was built with two databases, one delivered by Compete and the other by ANI. Both provide all relevant information regarding projects of SI I&DT from NSRF (2007-2013) and PT2020 (2014-2021). They present information on all projects of the system of incentives, being them approved or rejected, carried out individually or in copromotion. The data for each project is very rich, containing all the involved entities, including firms and entities from the STS, the monetary worth of the project (in terms of investment and subsidies), the activity sector, the technological area within the scope of the project, all the details regarding the application and also, details on the technical bodies responsible for the application, evaluation, financing, and oversight of the project.

The information from those two datasets was then merged with the Central Balance Sheet Database (CB), a very rich firm-level database made available by Banco de Portugal with yearly economic and financial information of all the non-financial Portuguese corporations between 2006 and 2019. From CB, firm-level data was retrieved on the average worker productivity, the average wage per worker, the number of total workers, the tangible and intangible assets, the dimension and age of the firm, and, finally, the level of exports and total sales. Given that CB only has data until 2019, and its information is paramount to the analysis, it will only be considered in this dissertation the period until 2019. This implies that 505 approved projects in copromotion, referring to 2020 and 2021, are not considered. We will only consider projects undertaken in mainland Portugal.

The following two subsections will present descriptive statistics describing the copromotion projects carried out in Portugal between 2007 and 2019 and the entities involved. Second, we will characterise the probability of firms having copromotion projects and how their approval might vary, given their characteristics.

3.2 Descriptive Statistics

Table 1 presents an overview of copromotion projects developed in NSRF and PT2020. Across the two frameworks, there were 1,240 entities involved (with 326 carrying out projects in PT2020 and NSRF) across 1,224 projects in copromotion. These projects amounted to 1,421 million euros in total investment, from which European funds subsidised 805 million euros.

PT2020 awards almost two times more incentives with fewer projects. Moreover, on average, during PT2020, each project received 107% more incentives, and, at the median, the value of the supports increased by 56%, showing that the projects in PT2020 were significantly larger.

Additionally, PT2020 also presents more entities involved and bigger projects in terms of members (in NSRF, 48% of the projects had two members by project, and 27% had three, while in PT2020, 35% of the undertakings had three members and projects with two entities accounted for 33% of the total.

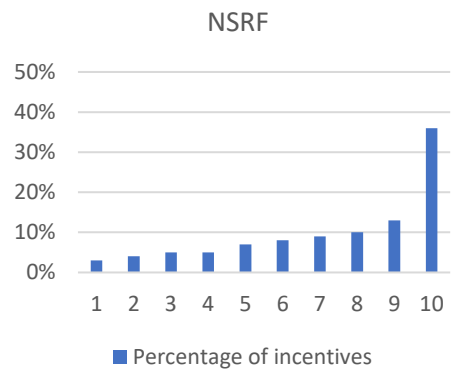
Table 1 *- Characterization of projects in copromotion supported by the ERDF in NSRF and PT2020, mainland Portugal*

	NSRF (2007-2013)	PT2020 (2014-2019)
Number of projects	637	587
Entities	738	828
Members by project		
Average	3.28	3.81
Mode	2	3
Standard deviation	3.12	4.35
Min.	1	2
P10	2	2
Median (P50)	3	3
P90	5	5
Max.	39	47
Total of incentives (M €)	276,97	527,70
Average (th €)	434,8	899,0
Standard deviation (th €)	563,2	1 944,9
Min (th €)	40,3	107,7
P10 (th €)	145,8	263,5
Median (P50) (th €)	317,7	495,7
P90 (th €)	700,0	1 104,1
Max (th €)	6 455,9	21 073,8

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively.
Source: Own computations using data provided by Compete.

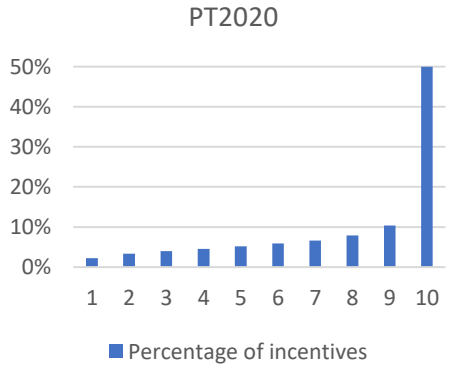
Figures 1 and 2 illustrate how the funds are distributed across the deciles of the projects. The statistics show a concentration of incentives in the top decile, which increased from NSRF to PT2020. In NSRF, the 10th decile receives 36% of the funds attributed in NSRF, and in PT2020, it received 50% of the incentives.

Figure 1 *- Decile distribution of incentives by project in NSRF*



Source: Own computations using data provided by Compete.

Figure 2 *- Decile distribution of incentives by project in PT2020*



Source: Own computations using data provided by Compete.

3.2.1 Characterisation of the firms in copromotion projects

Of the 1,120 firms involved, 257 (23% of the total) had projects in NSRF and PT2020. However, as observed in Table 2, the number of firms in PT2020 increased by 11% by 2019.

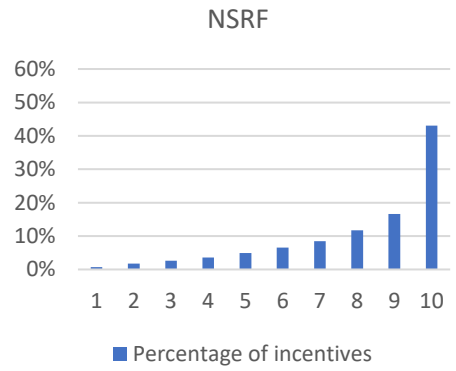
Table 2 *- Characterization of the participation of firms in projects in copromotion, supported by the ERDF in NSRF and PT2020*

	NSRF (2007-2013)	PT2020 (2014-2019)
Firms	652	725
Projects participation		
Average	1.72	1.61
Mode	1	1
Standard deviation	1.58	1.23
Min.	1	1
P10	1	1
Median (P50)	1	1
P90	3	3
Max.	14	9
Total of incentives (M €)	151,73	289,61
Average (th €)	232,72	399,46
Standard deviation (th €)	364,24	1 726,65
Min (th €)	0	0
P10 (th €)	30,12	39,58
Median (P50) (th €)	128,94	177,47
P90 (th €)	501,98	707,37
Max (th €)	5 644,08	44 530,78

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively. Source: Own computations using data provided by Compete.

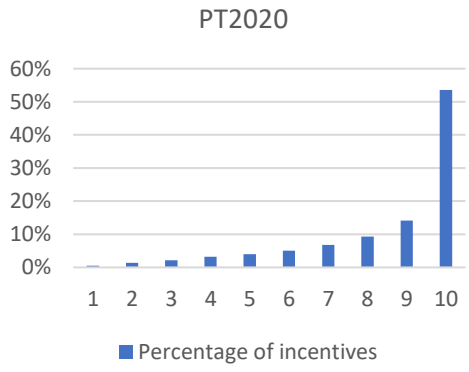
In PT2020, the average amount of incentives received by firms increased by 72% compared to NSRF. Yet, at the median, the incentives increased by 38%, less than the average, indicating a larger share of incentives being attributed to the most subsidised firms in PT2020.

Figure 3 *- Decile distribution of incentives by firms in NSRF*



Source: Own computations using data provided by Compete.

Figure 4 *- Decile distribution of incentives by firms in PT2020*



Source: Own computations using data provided by Compete.

Figures 3 and 4 show the decile distribution of funds by the involved firms. The statistics reveal a concentration of funds in the top 10% of most subsidised firms and confirm a higher concentration during PT2020, with an increase of 11 p.p., going from 43% to 54% of the total funds.

Table 3 *- Distributions of projects in copromotion by firm size, in NSRF and PT2020*

	NSRF (2007-2013)				PT2020 (2014-2019)			
	Firms	Projects	Incentives	Investment	Firms	Projects	Incentives	Investment
Micro	24 %	23 %	19%	15 %	19 %	14 %	11 %	8 %
Small	26 %	24 %	27%	22 %	27 %	26 %	21 %	18 %
Medium	25 %	22 %	22%	22 %	31 %	31 %	25 %	23 %
Large	25 %	31 %	32%	41 %	23 %	29 %	43 %	51 %
TOTAL	100 %	100 %	100%	100 %	100 %	100 %	100 %	100%

Source: Own computations using data provided by Compete.

Table 3 shows a balanced distribution of firms by size in NSRF, which is more unbalanced in PT2020, with more small and medium firms involved compared to micro and large ones. Yet, larger firms get a more significant share of the projects and the awarded incentives. Larger firms are also the ones with more investment made, which leads to them receiving more funds. It is also noticeable the increase in the share of funds awarded to medium and larger firms in PT2020.

3.2.2 Characterisation of the entities from the STS in copromotion projects

STS entities are all non-profit research and development organisations in the State, higher education, and private sectors. However, even among these entities, there are different types of institutions. This dissertation defines three categories to understand better the scope of the actors: (1) Higher education institutions (HEI); (2) Interfaces (entities recognised by ANI that act in the intermediate space of the innovation system, developing and promoting innovation by facilitating the transfer of knowledge from higher education institutions to the industry); and (3) all the other entities not included in the two previous classifications (includes research centres, independent laboratories; etc.).

A subsection will be dedicated to each type of institution; firstly, it will be analysed all the entities from the STS together. Table 4 presents the primary metrics of these entities, following the structure used to characterise the firms. The number of research institutions increased from 86 to 103, from NSRF to PT2020 (an increase of 20%), with 69 entities participating in both frameworks from a total of 120 entities from the STS.

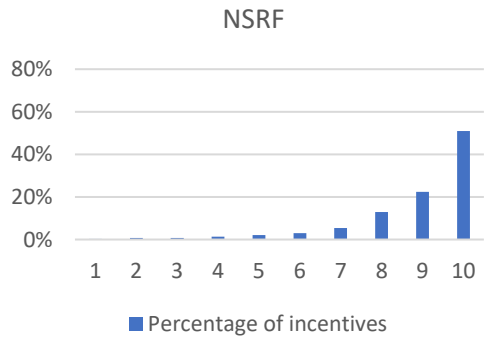
Table 4 *- Characterization of the participation of entities from the STS in projects in copromotion, supported by the ERDF in NSRF and PT2020*

	NSRF (2007-2013)	PT2020 (2014-2019)
Entities from the STS	86	103
Higher education institutions	26	27
Interfaces	23	25
Others	37	51
Projects participation		
Average	11.10	10.36
Mode	1	1
Standard deviation	17.59	17.02
Min.	1	1
P10	1	1
Median (P50)	4	4
P90	25	29
Max.	95	88
Total of incentives (M €)	125,24	238,08
Average (th €)	1 456,25	2 311,42
Standard deviation (th €)	2 398,11	6 368,27
Min (th €)	18,91	15,77
P10 (th €)	68,27	58,26
Median (P50) (th €)	344,64	336,94
P90 (th €)	4 056,92	5 180,74
Max (th €)	10 967,32	54 110,16

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively. Source: Own computations using data provided by Compete.

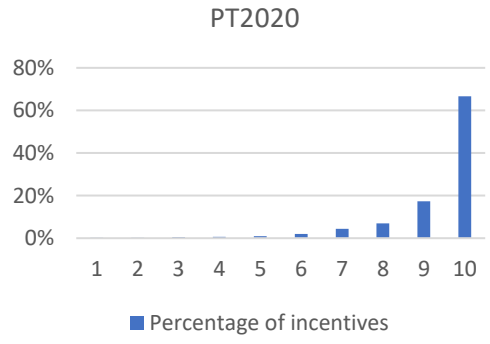
On average, entities from the STS received 59% more incentives in PT2020, however, at the median, the increase was not proportional, as it decreased. On the other hand, the percentile 90 increased by 28%, and the maximum became five times larger. The stability in the percentile 10 and an increase of the standard deviation point to a concentration of funds in a small group of entities in PT2020.

Figure 5 *- Decile distribution of incentives by entities from the STS in NSRF*



Source: Own computations using data provided by Compete.

Figure 6 *- Decile distribution of incentives by entities from the STS in PT2020*



Source: Own computations using data provided by Compete.

Figures 5 and 6 reinforce the conclusion of a higher concentration of incentives in PT2020, with the 10th decile presenting a significant increase of 16 p.p. and percentage decreases registered in the bottom deciles.

Characterisation of the higher education institutions

HEI represent 31% of all the entities from the STS involved in copromotion projects. Table 5 presents the statistics regarding the projects with the participation of these entities. Higher education institutions were part of 64% and 71% of the projects, received 22% and 31% of all the incentives awarded, and invested 23% and 27% of the total in NSRF and PT2020, respectively.

Table 5 *- Characterization of the participation of universities and polytechnics in projects in copromotion, supported by the ERDF in NSRF and PT2020*

	NSRF (2007-2013)	**PT2020 (2014-2019)**
Number of projects	407	416
Projects participation		
Average	20.50	22.59
Mode	1	3
Standard deviation	27.39	44.48
Min.	1	1
P10	1	1
Median (P50)	6	11
P90	68	79
Max.	95	88
Total of incentives (M €)	61,95	163,84
Average (th €)	2 382,70	6 068,30
Standard deviation (th €)	3 392,81	11 473,68
Min (th €)	20,55	26,32
P10 (th €)	87,24	143,62
Median (P50) (th €)	618,36	1 432,08
P90 (th €)	8 238,77	21 304,15
Max (th €)	10 967,32	54 110,16

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively.
Source: Own computations using data provided by Compete.

On average, HEI participated in more projects in PT2020 than in NSRF (while in NSRF, 16 entities participated in a single project, in PT2020, only three participated in just one). The increased importance of these institutions is also shown through the incentives received (on average, they received 2.5 times more, and the median became 2.3 times higher).

Table 6 *- Distribution of firms involved in projects that include higher education institutions by size, in NSRF and PT2020*

	Micro	Small	Medium	Large	TOTAL
NSRF	25 %	26 %	24 %	25 %	100 %
PT2020	19 %	27 %	31 %	23 %	100 %

Source: Own computations using data provided by Compete.

Tables 19 show the distribution of firms by their size through the different groups of firms. It is represented a balanced distribution, with a decrease in the weight of micro-firms and an increase for medium, on these partnerships during PT2020.

Characterisation of the intermediary organisations

In articulation with ANI, the Portuguese government officially recognised 31 entities as intermediary institutions, classifying them as interfaces. This subsection will give information regarding the interfaces involved in copromotion projects following the previous structure used for higher education institutions.

Of the 31 recognised interfaces, 26 got involved in at least one project in copromotion, and 22 of them had projects in both frameworks, representing 22% of all the involved entities of the STS. In terms of projects, interfaces were involved in 39% and 43% of the projects, were awarded 19% and 7% of all the incentives and were responsible for 15% and 12% of the total investment in NSRF and PT2020, respectively.

From Table 7, we perceive that, until 2019, the activity of interfaces regarding projects in copromotion was relatively similar to what was recorded during NSRF, with slight variations in the average and the median. These entities also participated in roughly the same number of projects in NSRF and PT2020.

Table 7 *- Characterization of the participation of interfaces in projects in copromotion, supported by the ERDF in NSRF and PT2020, mainland Portugal*

	NSRF (2007-2013)	PT2020 (2014-2019)
Number of projects	246	251
Projects participation		
Average	14	13.44
Mode	3	2 / 3 / 15
Standard deviation	10.19	10.16
Min.	1	1
P10	3	2
Median (P50)	13	12
P90	30	30
Max.	37	34
Total of incentives (M €)	52,91	61,87
Average (th €)	2 300,22	2 474,94
Standard deviation (th €)	2 207,65	2 132,13
Min (th €)	100,49	92,97
P10 (th €)	192,54	162,53
Median (P50) (th €)	1 600,84	2 233,66
P90 (th €)	4 475,19	5 906,74
Max (th €)	8 264,48	6 796,88

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively.
Source: Own computations using data provided by Compete.

Table 8 reflects a tendency for more partnerships between larger firms and interfaces compared to the observed values for higher education institutions, with the smaller share attributed to micro firms. This table appears to support the argument of Freitas et al. (2013), who states that larger firms look more for institutional partnerships with intermediary organisations.

Table 8 *- Distribution of firms involved with interfaces by size, in NSRF and PT2020*

	Micro	Small	Medium	Large	TOTAL
NSRF	19 %	27 %	27 %	27 %	100 %
PT2020	17 %	26 %	32 %	25 %	100 %

Source: Own computations using data provided by Compete.

3.2.3 The composition of consortiums

As discussed above, some studies show that different partnerships affect the impacts of the subsidies (see, e.g. Belderbos et al., 2004; Aschhoff & Schmidt, 2008). This subsection will dwell on the characteristics of the consortiums funded by NSRF and PT2020, describing their composition in terms of firms' characteristics and the participation of the different entities of the STC.

Firstly, Table 9 presents the share of projects with some particular characteristics, such as the presence of micro or large-sized firms in the consortium, an exporter firm, and having multiple firms or entities from the STS in the partnership, among others.

Table 9 *- Characterization of projects by their consortiums in % of the total, for NSRF and PT2020*

	NSRF	**PT2020**
	% of Total Projects	% of Total Projects
Project with Micro Firm	33	28
Project with Large Firm	28	27
Project with an exporter firm	81	89
Project with firms with R&D employees	54	53
Project with more than 1 firm	39	46
Project with more than 1 entity from the STS	35	53
Projects with firms from more than 1 district	33	34

Source: Own computations using data provided by ANI merged with CB.

From Table 9, it is clear how in PT2020, compared to NSRF, the number of projects with multiple firms and entities from the STS increased, especially regarding the latter. It is also possible to perceive an increase in projects with an exporter firm, with a large share of projects having the presence of at least one exporter firm, and, on the contrary, a slight decrease for projects with micro firms.

Table 10 *- Characterization of partnerships including only one firm, in % of the total, by size, in NSRF and PT2020*

NSRF				
	Entities from the STS			**Total Projects**
	Interface	HEI	Other STS	
Micro	21%	73%	19%	78
Small	32%	69%	14%	118
Medium	37%	69%	11%	91
Large	40%	73%	10%	70
PT2020				
	Entities from the STS			**Total Projects**
	Interface	HEI	Other STS	
Micro	28%	85%	13%	39
Small	30%	75%	22%	93
Medium	45%	72%	19%	99
Large	40%	65%	11%	72

Source: Own computations using data provided by ANI merged with CB.

From the table above, regarding the projects, with just one firm within the consortium, it is noticeable how the presence of interfaces increases for larger firms. On the other hand, the higher education institutions in PT2020 present a different trend by being more present in projects with smaller firms. The number of projects involving just one micro firm decreased by 50% from NSRF to PT2020.

Table 11 *- Characterization of partnerships with more than one firm, in % of the total, by size, in NSRF and PT2020*

NSRF								
	Firms				Entities from the STS			Total Projects
	Micro	Small	Medium	Large	Interface	HEI	Other STS	
Micro	21%	50%	34%	27%	48%	58%	14%	86
Small	27%	35%	43%	33%	51%	50%	14%	159
Medium	25%	58%	30%	32%	56%	56%	18%	118
Large	25%	57%	41%	29%	57%	53%	25%	93
PT2020								
	Firms				Entities from the STS			Total Projects
	Micro	Small	Medium	Large	Interface	HEI	Other STS	
Micro	18%	60%	52%	20%	46%	70%	22%	105
Small	39%	36%	47%	22%	45%	75%	23%	162
Medium	40%	55%	30%	27%	54%	68%	16%	139
Large	28%	48%	49%	29%	60%	65%	19%	75

Source: Own computations using data provided by ANI merged with CB.

Table 11, by evaluating partnerships involving more than one firm, illustrates how small firms are the most usual partners for firms of different sizes, followed by medium firms. Concerning micro firms, their presence increased in projects with small and medium firms during PT2020. Conversely to what was observed in Table 10, their total number of projects with multiple firms increased. Large firms, in PT2020, presented a trend of increased participation in partnerships with larger firms. For the partnerships with entities from the STS, interfaces partner more with larger firms with a more prominent presence of higher education institutions in the partnerships with smaller firms. These partnerships reinforce, once again, the explanation presented earlier by Freitas et al. (2013) regarding intermediary institutions and large firms.

Tables 12 and 13, presented below, evaluate the consortiums on a firm-based analysis by showing some dispersion measures of the firm's characteristics within the same joint venture, namely the ratio of the maximum over the minimum, and the standard deviation, of some variables. The goal is to understand how different the firms engaged in partnerships were and measure their variability within the same project. From the tables, it is observed that usually, the higher the number of members in the consortium, the higher the dispersion and differences between the firms at the extremes, except for the productivity, where there is a trend of larger projects having more similar members in terms of productivity.

Table 12 *– Dispersion measures of characteristics of firms within the same project, in NSRF*

NSRF			
Dimension	**Firms by Project**	**Av. Ratio (Max./Min.)**	**Av. Standard Deviation**
Productivity (€)	2 Firms	2.63	59.13
	3 or 4 Firms	4.04	29.42
	5 Firms or more	6.78	21.04
Exports (€)	2 Firms	1 617.48	19 504,00*
	3 or 4 Firms	8 455.95	15 257,93*
	5 Firms or more	37 309.66	18 108,23*
Nº of workers (€)	2 Firms	47.79	258.15
	3 or 4 Firms	26.39	185.04
	5 Firms or more	107.00	186.76
Wage per Employee (€)	2 Firms	1.50	6 125.62
	3 or 4 Firms	2.21	10 955.76
	5 Firms or more	2.90	8 158.91

Source: Own computations using data provided by ANI merged with CB. **Values in thousands.*

Table 13 *- Dispersion measures of characteristics of firms within the same project, in PT2020*

PT2020			
Dimension	**Firms by Project**	**Av. Ratio (Max./Min.)**	**Av. Standard Deviation**
Productivity (€)	2 Firms	2.47	27.96
	3 or 4 Firms	3.95	26.27
	5 Firms or more	9.79	23.99
Exports (€)	2 Firms	327.74	27 952.03*
	3 or 4 Firms	15 761.70	23 224.66*
	5 Firms or more	4 630.87	118 523.54*
Nº of workers (€)	2 Firms	15.34	165.90
	3 or 4 Firms	92.96	208.06
	5 Firms or more	203.87	268.54
Wage per Employee (€)	2 Firms	1.54	6 527.52
	3 or 4 Firms	2.21	7 328.65
	5 Firms or more	3.85	9 286.31

Source: Own computations with using provided by ANI merged with CB. **Values in thousands.*

3.3 Participation and approval determinants

As acknowledged in the literature, participation in copromotion projects is not random and varies depending on the characteristics of the firms. This subsection will present the characteristics of candidate firms to copromotion and individual projects (with approved or rejected projects), as well as of all firms

of the Portuguese business sector. After the comparison, it will be estimated how the probability of engaging in copromotion projects and having those projects approved may depend on some of those characteristics.

Table 14 reports the descriptive characteristics of all the 3,272 firms that applied for at least one copromotion project, for the 3,458 candidate firms for individual projects, and finally, for all the 269,848 firms from the Portuguese business sector, in the year 2019.

Table 14 *- Characteristics of all candidate firms for copromotion projects, individual projects, and of all firms of the Portuguese business sector, in the year 2019*

Firms involved in copromotion projects							
	Employees	Assets (€ th.)	Sales (€ th.)	Productivity (€ th.)	V.A. (€ th.)	Exports (€ th.)	Wage p/ Employee (€ th.)
Average	157.33	25 851,0	43 049,12	91,18	10 692,89	18 578,05	26,14
SD	501.64	197 470,02	302 473,04	1 055,09	52 926,48	158 942,36	12,72
P10	5	34,09	201,22	17,32	129,88	0	15,20
Median	41	1 266,76	4 502,70	34,48	1 717,73	741,95	23,86
P90	306	16 319,15	45 867,10	72,52	13 714,79	19 487,79	38,56
Firms involved in individual projects							
	Employees	Assets (€ th.)	Sales (€ th.)	Productivity (€ th.)	V.A. (€ th.)	Exports (€ th.)	Wage p/ Employee (€ th.)
Average	91.80	5 705,07	15 513,69	41,26	4 639,63	8 738,24	24,89
SD	232.22	23 812,46	61 396,64	35,50	17 090,86	53 198,29	11,30
P10	4	28,00	191,90	15,55	96,65	0	13,76
Median	29	741,02	2 667,19	32,98	996,83	417,27	22,68
P90	217	9 699,44	27 430,19	69,22	8 400,97	12 695,99	38,67
All firms from the Portuguese business sector							
	Employees	Assets (€ th.)	Sales (€ th.)	Productivity (€ th.)	V.A. (€ th.)	Exports (€ th.)	Wage p/ Employee (€ th.)
Average	10.59	534,68	1 316,92	30,16	336,56	283,81	14,61
SD	114.97	15 322,41	27 279,34	696,15	5 128,63	12 521,84	13,59
P10	1	0	27,67	5,94	9,64	0	6,47
Median	3	18,07	151,95	17,39	55,38	0	12,36
P90	15	411,87	1 351,02	46,85	404,65	39,72	24,22

Note: P10 stands for percentile 10 (likewise for the other statistics). Min and Max represent the minimum and the maximum, respectively. V.A. represents the value added by the company. Source: Own computations using data provided by ANI merged with CB.

Firms applying for R&D projects, individually or copromotion, are much larger than the average Portuguese firm. However, distinguishing between the two modalities, it is possible to perceive how firms that applied for copromotion projects are, on average, larger.

3.3.1 Characterisation of the probability of firms having copromotion projects. a *probit* model analysis

The statistics presented in Table 14 suggest that copromotion applicants are larger and more productive. We will now use a limited dependent variable model to test that assessment. We will specifically use a *probit* estimator.

A *probit* model is an estimation procedure used for situations where there are only two possible outcomes; namely, $Y_i = 1$ or $Y_i = 0$. In our context, the model will estimate the probability of a specific event occurring (when $Y_i = 1$), where that probability is given by $P(Y_i = 1)$ and is calculated by the maximum likelihood method and the pseudo-R^2 estimation (for measuring the explanatory capability of the model), through the following equation:

$$P(Y_I = 1|X_i) = F(x_i\beta) = \phi(x_i\beta) = \int_{-\infty}^{x_i\beta} \frac{1}{\sqrt{2\pi}} e^{\frac{1}{2}z^2} dt$$

where X_i is a vector that represents the independent variables that affect the probability of $Y_i = 1$ occurring. In our case, X_i will include the firms' characteristics. In the equation, ϕ represents the normal distribution of the probability function. It will relate the non-linear relationship between the explanatory variables and the outcome Y_i and ensure that the estimated probability is restricted to the interval [0,1]. The estimated parameters have no direct interpretation in terms of magnitude. To quantify the relationship between the regressors and the dependent variable, we can calculate the marginal effects associated with each one of the explanatory variables through partial derivatives.

3.3.2 Probability of applying for copromotion projects

The first model to be estimated will have $Y_i = 1$ when firm i has applied for a project in copromotion, 0 otherwise. As explanatory variables, we include the log of the firm's level of productivity (measured by the average gross added value per worker), the log of the number of workers, the age of the firm (it will also be included in the specification of the model the age squared, to assess if there are diminishing effects of firms' age) and their tangible and intangible assets, both in log. The economic activity sector

and the district of the firm are also included in the model to control for sectorial and geographical specificities.[2]

The tables to be presented below will show the marginal effects of the independent variables, meaning that the values of each parameter represent the variation in the probability of an event occurring (in our case, for applying to a project in copromotion and having its application approved) for marginal variations of the regressors. In what follows, we estimate the marginal effects of a firm at age 10 (as it is the median age of the firms in the sample).

The estimations rely on a sample of 4,043 firms that have applied for an R&D project. The funding application could be approved or rejected in either modality (copromotion or individual), with 1,971 firms having applied for copromotion projects. The candidates for individual projects are 2,898 firms, with 826 having applied for both types. Each observation is considered in the year where the application was made or rejected. The marginal effects for 'applied for a project in copromotion' are presented in Table 15.

Table 15 – *Firm probability of applying for Copromotion Projects (probit model)*

	M(1)	M(2)
Log Employment	0.155***	0.101***
	(0.020)	(0.022)
Log Productivity	0.115***	0.101***
	(0.024)	(0.026)
Age	0.006***	0.007***
	(0.002)	(0.003)
Log Intangible Assets	0.009***	0.0004
	(0.003)	(0.004)
Log Tangible Assets	-0.007	-0.012
	(0.008)	(0.009)
Observations	7145	6099
Pseudo-R^2	0.172	0.184
Log-likelihood	-4087.87	-3431.06

Notes: Robust standard errors in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. M(1) corresponds to the sample of all the 4043 firms that have applied for an R&D project. M(2) excludes from the sample 536 firms that had applications for both copromotion and individual projects in the same year. The activity sector and the district are also included in the model as control variables.
Source: Own computations using data provided by ANI merged with CB.

In model M(1), the estimation is for the entire sample of 4,043 firms, while model M(2), as a robustness check, drops 536 observations that applied for both modalities in the same year. It is possible

[2] By performing a Wald Test it is shown that their inclusion is relevant to the model's estimation.

to conclude from Table 15 that firms that apply for copromotion projects employ more workers, are more productive, and are older. It is possible to see through M(1) that, for firms 10% more productive, the probability of applying for a copromotion project increases by about 1.2 p.p. (percentage points), while for the employment, having 10% more employees increases that probability by 1,6 p.p.

These conclusions are sustained in M(1) and M(2) with slight coefficient variations. The intangible assets are an exception, having a positive and statistically significant coefficient in M(1) but statistically non-significant in M(2). The tangible assets of the firms do not seem to be determinant on the probability of a firm applying for a project in copromotion.

3.3.3 Probability of having an application for copromotion approved

The second *probit* model, presented in this subsection, considers $Y_i = 1$ when firm i has an application for copromotion approved and 0 otherwise. The aim is to explain how the probability of having their project approved depends on the firm's characteristics. The explanatory variables considered will be the same as for the *probit* presented in Table 15, including an additional dummy variable that will equal 1 for situations where a firm already has past experience in copromotion applications (if a firm applied for a copromotion project in a prior year, it does not matter if the application was approved or rejected, it is considered that the firm has past experience, and the variable will equal 1).

The estimation of the model, presented in Table 16, comprises only firms that applied for projects in copromotion in the year of the application. Model 1, M(1), has all the 1,971 applicants, while in model 2, M(2), firms that had at least one project approved and another one rejected in the same year are not considered (a total of 216 firms).

Table 16 shows that both the productivity and the number of workers are determinants in the approval of copromotion projects. According to M(1), firms with 10% more employees and 10% more productive have a higher likelihood of being approved, by about 1,1 p.p. and 0.9 p.p., respectively. The new variable, of having prior experience in applications for copromotion projects, has a powerful and statistically significant effect, at a 5% significance level, on the probability of having an application for a project in copromotion approved. Prior experience is associated with a 14 p.p. increase in the chances of having their projects approved. However, this result is not statistically significant in M(2). The firm's age appears only to be impactful when we consider model 2, while neither tangible nor intangible assets affect the probability of having the project approved in both estimations.

Table 16 *– Firm probability of having an application for a project in copromotion approved (probit model)*

	M(1)	M(2)
Log Employment	0.094***	0.066**
	(0.028)	(0.030)
Log Productivity	0.107***	0.089**
	(0.038)	(0.041)
Prior Applications	0.143**	0.012
	(0.060)	(0.064)
Age	0.003	0.006*
	(0.003)	(0.003)
Log Intangible Assets	0.008	0.005
	(0.005)	(0.006)
Log Tangible Assets	0.010	0.013
	(0.012)	(0.013)
Observations	3463	3147
Pseudo-R^2	0.155	0.168
Log-likelihood	-2027.03	-1793.12

Notes: Robust standard errors in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. M(1) corresponds to the sample of all the 1971 firms that applied for copromotion projects. M(2) excludes from the sample 216 firms that had approved and rejected copromotion projects in the same year. The activity sector and the district are also included In the model as control variables.
Source: Own computations using data provided by ANI merged with CB.

Summing up, the estimations presented in Table 15 confirm the expectations hinted from the statistics presented in Table 14, i.e., firms involved in projects in copromotion are larger and more productive compared to the candidate firms for individual projects. Among the candidates for copromotion, the ones who have their projects approved are also the larger and more productive ones, with some ambiguous effects dependent on their age and past experience with applications. These results support the views of authors who believe that the management entities act according to the picking the winner's method, choosing firms with higher chances of success in their projects (Blanes & Busom, 2004; Aguiar & Gagnepain, 2017; Barajas et al., 2012).

4 Analysis of the determinants of firms' performance

The current chapter will tackle the research questions presented in the introduction, namely:

1) What are the impacts of R&D copromotion projects on firm performance, and how do they compare to the effects of individual projects?
2) How does the composition of the consortium affect the impacts on firm performance?

Through the CB, it was possible to generate a rich panel dataset from 2006 to 2019, with 547,309 firms. To answer the proposed questions, there are three possible approaches. It is possible to use an OLS (ordinary least squares) estimation if all the variables are observed, as it produces consistent estimates. However, for panel data, where the same individual is observed through time and, consequently, we have autocorrelation from different observations of the same individual, the OLS is not ideal, as it ignores this autocorrelation. Therefore, a random-effects or a fixed-effects model is preferable, as they take advantage of the longitudinal feature of our data.

Between those two approaches, the use of fixed-effects is most likely preferred to a random-effects procedure, given that, for a firm to participate in either a copromotion project or an individual one, it first needs to apply for it. This hints that the assignment to the treatment is not random; therefore, there is a high chance of unobserved heterogeneity correlated with the estimated covariates. Moreover, as shown in the *probit* regressions, even within the candidate firms, some of their characteristics influence the probability of having their projects approved, reinforcing the non-random odds of receiving the treatment. By using a fixed-effects model, we are controlling for this unobserved heterogeneity and producing consistent estimates.

To fully attest that the fixed-effects is the most efficient model to be estimated, for each research question is made a Hausman test to verify the validity of this approach over the random-effects. The Hausman test will assess any correlation between the estimators and the error term, with the null hypothesis being that there is no correlation between them. Rejecting the null hypothesis means that the random-effects estimator is not adequate. The statistic underlying the Hausman test is defined as:

$$\omega = \left[b - \hat{\beta}\right]' \left[Var(b) - Var\left(\hat{\beta}\right)\right]^{-1} [b - \widehat{\beta}] \sim \mathcal{X}^2_{(k)}$$

where k represents the number of elements in b, and, under the null hypothesis, b Is a consistent estimator and $\hat{\beta}$ Is an efficient estimator.

The models to be estimated will be in line with the following equation:

$$y_{i,t+1} = X_{i,t}\beta + \eta_i + \varepsilon_{i,t}$$

where y_{it} corresponds to the outcome variables we ought to measure for each firm i in period t, and η_i are the time-invariant unobserved components of firm i. This term η_i can be estimated. It is a mean of all elements (observed and unobserved) that do not vary within firms and captures the unobserved heterogeneity associated with each unit under observation.

As outcome variables, we consider the average productivity per worker (calculated as before, for the estimation of the *probit* models, by the average gross added value per worker), the total employment, and the reported volume of exports and sales. All the effects will be lagged by one year to account for a possible delay of the impact of projects in copromotion on the performance of the involved firms.

The estimation results, as well as the details on the inference, will be presented in the following subsections. Firstly, it will be answered the question of which modality, between individual and copromotion projects, offers more comparative advantages. Next, the final subsection of this chapter dwells on the evaluation of the diffusion potential within consortiums for specific characteristics of its members.

4.1 Copromotion vs Individual applications

Based on the assessment from the Hausman test, our preferred estimates will be the ones computed from the fixed-effects estimator. Given the structure of autocorrelation and heteroskedasticity present in our data and econometric formulation of the model, we will report standard errors clustered at the firm level. In the estimation of the current model, it will only be considered firms that applied for at least one project within the SI I&DT. It could be for any of the modalities: in copromotion or individually (it also includes firms that only had rejected applications and never carried out an R&D project). Thus, the final sample comprises 4,043 firms (1,971 candidates for projects in copromotion and 2,898 applicants for individual projects).

In the first step, it will be estimated the results for the entirety of the sample, and then, it will be made four similar estimations but for each firm size. The model is specified as follows:

$$Y_{i,t+1} = \beta_1 + \beta_2 TCoProm_{i,t} + \beta_3 TInd_{i,t} + \beta_4 TCoProm_{i,t} TInd_{i,t} + \beta_5 Tang.Assets_{i,t} + \beta_6 Intan.Assets_{i,t} + \sum_{j=7}^{8} \beta_j Z_{j,i,t} + \eta_i + \lambda_t + \varepsilon_{i,t}$$

The dependent variables represented by $Y_{i,t+1}$ are the logarithms of the average productivity per worker, the sales, the exports and also the number of workers of firm i, all in period $t+1$. The model also controls for the year, the activity sector, and the district of the firm so that it can account for a specific industry, geographical, and yearly shocks (a Wald test validates the significance of the three parameters). The independent variables used are:

- $TCoProm_{i,t}$ - is a dummy variable that equals 1 in years where firm i carried out a project in copromotion
- $TInd_{i,t}$ - is a dummy variable that equals 1 in years where firm i carried out an individual project
- $TCoProm_{i,t}TInd_{i,t}$ - represents the interaction of the previous two dummy variables and assesses the effects for firms that carried out both individual and copromotion projects in the same year.
- $Tang.Assets_{i,t}$ - is the logarithm of the value of the tangible assets of firm i in year t.[3]
- $Intan.Assets_{i,t}$ - is the logarithm of the value of the intangible assets of firm i in year t.[4]
- $Z_{j,i,t}$ – contains the effects attributed to the activity sector and the district of the firm: $ActivitySector_{i,t}$; $District_{i,t}$.
- η_i – captures the time-invariant characteristics of the firms'
- λ_t– represents the effects from each period t
- $\varepsilon_{i,t}$ – defines the error term

The results for the first estimation are presented in Table 17, and it is possible to conclude that projects in copromotion impact the various dependent variables differently. Regarding productivity, while undertaking individual projects has no statistically significant effect, carrying out a copromotion project increases productivity by about 3% in the year immediately after the completion of the venture (at a significance level of 5%). For employment, both types of undertakings have a positive impact, with an expected increase of around 7%, in the year following the end of the project.

Looking at exports, the return to copromotion, although positive, is not statistically significant. For this outcome measure, the impact associated with individual projects is almost 15%. In terms of sales, the results point to a more substantial impact, in the order of 2 p. p., of individual projects in comparison to joint ventures (with the firsts increasing sales by around 7% and the second being fixated at 5%, but only at a 5% significance level). Finally, carrying out individual and copromotion projects simultaneously has no evident impact on any performance measure considered in the models.

[3] Following the argument of Santos (2019), the tangible assets are used as a control for the firm's productive capacity, as a proxy of its physical capital.
[4] Following the argument of Santos (2019), the intangible assets are used as control for the firm's innovative capacity, as a proxy for R&D activities.

Table 17 *- Impacts on Productivity, Employment, Exports, and Sales (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.029**	0.071***	0.024	0.053**
	(0.014)	(0.011)	(0.089)	(0.021)
TInd	0.013	0.074***	0.147**	0.068***
	(0.011)	(0.011)	(0.074)	(0.018)
TCoProm x TInd	-0.032	0.035	-0.014	0.019
	(0.027)	(0.023)	(0.175)	(0.038)
Intang. Assets	0.002**	0.009***	0.034***	0.011***
	(0.001)	(0.001)	(0.007)	(0.002)
Tang. Assets	0.014***	0.067***	0.165***	0.088***
	(0.003)	(0.004)	(0.020)	(0.007)
Hausman Test	1122.2***	-	2740.2***	1475.0***
Observations	40139	40139	40139	40139
Firms	4169	4169	4169	4169

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables. The Hausman Test for the Employment estimation developed an inconclusive result.
Source: Own computations. using data provided by ANI merged with CB.

It is also essential to highlight the significance that the assets have on the variation of the outcomes. Higher productive and innovative capacities are linked to increases in the studied outcomes, except for the level of intangible assets that do not affect the firms' productivity, at least in the year immediately after.

Next, four similar models make the same assessment but divide the samples by firm size. For firms that increased or decreased in dimension from 2006 to 2019, it is considered the mode of the dimension.

Table 18 *- Impacts on Productivity, Employment, Exports, and Sales for Micro Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.090**	0.134***	0.063	0.013
	(0.042)	(0.028)	(0.238)	(0.075)
TInd	0.033	0.117***	0.087	0.072
	(0.029)	(0.024)	(0.173)	(0.049)
TCoProm x TInd	-0.169*	0.043	-1.042*	0.052
	(0.100)	(0.084)	(0.588)	(0.116)
Intang. Assets	0.004	0.009***	0.035**	0.014***
	(0.003)	(0.002)	(0.015)	(0.004)
Tang. Assets	0.013***	0.047***	0.117***	0.070***
	(0.004)	(0.004)	(0.024)	(0.009)
Observations	13288	13288	13288	13288
Firms	1780	1780	1780	1780

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 19 *- Impacts on Productivity, Employment, Exports, and Sales for Small Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.042*	0.079***	0.181	0.093***
	(0.024)	(0.018)	(0.165)	(0.029)
TInd	0.010	0.058***	0.241**	0.069***
	(0.016)	(0.014)	(0.121)	(0.023)
TCoProm x TInd	-0.020	0.064*	0.063	-0.008
	(0.046)	(0.035)	(0.333)	(0.064)
Intang. Assets	0.002*	0.007***	0.028**	0.009***
	(0.001)	(0.001)	(0.011)	(0.002)
Tang. Assets	0.024***	0.091***	0.291***	0.117***
	(0.006)	(0.008)	(0.043)	(0.013)
Observations	15145	15145	15145	15145
Firms	1390	1390	1390	1390

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 20 *- Impacts on Productivity, Employment, Exports, and Sales for Medium Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.008	0.012	-0.066	0.021
	(0.015)	(0.018)	(0.116)	(0.032)
TInd	0.009	0.025	0.023	0.033*
	(0.015)	(0.017)	(0.106)	(0.019)
TCoProm x TInd	-0.022	0.068*	0.253	0.052
	(0.033)	(0.036)	(0.194)	(0.046)
Intang. Assets	-0.0003	0.011***	0.029***	0.010***
	(0.001)	(0.002)	(0.011)	(0.003)
Tang. Assets	0.006	0.091***	0.195***	0.093***
	(0.009)	(0.021)	(0.061)	(0.023)
Observations	8749	8749	8749	8749
Firms	753	753	753	753

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 21 *- Impacts on Productivity, Employment, Exports, and Sales for Large Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	-0.061	0.008	-0.416**	-0.019
	(0.038)	(0.026)	(0.200)	(0.032)
TInd	-0.020	0.079**	0.047	0.066*
	(0.032)	(0.040)	(0.147)	(0.039)
TCoProm x TInd	0.082	-0.007	0.201	0.010
	(0.060)	(0.045)	(0.212)	(0.049)
Intang. Assets	0.004	0.009***	0.019	0.011***
	(0.003)	(0.003)	(0.018)	(0.004)
Tang. Assets	0.001	0.063***	-0.112	0.073***
	(0.012)	(0.019)	(0.103)	(0.022)
Observations	2957	2957	2957	2957
Firms	246	246	246	246

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

From the comparison of Tables 18 till 21, the main finding is that smaller firms (including micro and small ones) have more benefits attributed to their participation in projects in copromotion than larger firms (including medium and large firms).

Micro firms are the type of firm that benefits the most in terms of productivity and employment from participating in copromotion projects. From Table 18, one concludes that micro firms' labour productivity and employment increase by 9% and 13%, respectively, after participating in a copromotion project. However, there are no significant effects regarding their exports and level of sales. Small firms' productivity and employment increases are lower (4% and 8%, respectively). Participating in a joint venture seems to increase sales of small firms by 7%. Finally, the results do not show any significant benefit for medium and large benefits from participating in copromotion projects, with large firms even registering a decrease in the exports in the year following the project conclusion.

As before, the impacts of higher productive and innovative capacity remain significant when explaining the evolution of the performance measure, but its effects decrease for larger firms. Making a distinction between modalities, in every parameter where the participation in copromotion projects is statistically significant, its impact is usually superior to the registered effect for participating in individual projects. The exceptions are when the copromotion's impact is negative on large firms' exports while individual projects are not statistically significant and when individual projects lead to increases but the copromotion modality is not statistically significant (which only is detected four times).

Finally, copromotion projects appear to favour smaller firms, while individual projects have more effects on larger ones. The results align with the literature by perceiving the benefits of engaging in copromotion projects are higher for smaller firms. Our outcomes are also aligned with the study of Alexandre (2021), which recognises that research joint ventures carried out in Portugal have bigger returns than individual undertakings. However, in our regressions, that is only clear for micro and small firms. The results reported in Tables 18 to 21 also recognise that R&D investments are a driver of employment, supporting the findings of other studies (OECD, 2010; Bellucci et al., 2016; Santos, 2019).

4.2 Consortium effects on firms' performance

The second research question aims to test whether partnering with larger firms provides positive externalities to smaller firms and if coordination problems arise from the number of partners. This assessment will be made using a similar model to the one presented before but with different independent variables. The dependent variables will be the same: logarithms of productivity, exports, sales, and the number of workers.

The number of partners that the firm had in a specific year t is measured through three dummy variables, where the base group will be firms with active projects in copromotion with just one other

partner. The dummies will account for firms that were involved with two entities, three or four partners, and for firms that carried out projects with five or more other entities.

Four ratios will be used to verify for possible diffusion spillovers within the consortiums, which measure the differences between firms within the same project. The ratios will measure differences in average productivity per worker, exports, number of workers, and average wage per employee (used as a proxy for the labour force qualifications) between firm i and the firm within the same consortium, which has the maximum value for each performance measure. They will be calculated by dividing the maximum value by the value of each firm i.

Firms that participated in projects from both modalities, even though in different years, are dropped because the focus of this estimation will be firms in joint ventures. This way, it avoids possible lagged effects from past individual projects and, consequently, skewed results. As before, a Hausman test attested that a fixed-effects approach was preferable to a random-effects. It was also implemented Wald tests to the control variables, namely the economic activity sector, the district, and the year, which proved that their inclusion in the model was relevant.

The sample used in the following estimations comprises a total of 3,785 firms, from which 2,246 do not have any project approved, 968 carried out individual projects, and 571 undertook copromotion projects. The model estimated is as follows:

$$Y_{i,t+1} = \beta_1 + \beta_2 TCoProm_{i,t} + \beta_3 TInd_{i,t} + \beta_4 Partners2_{i,t} + \beta_5 Partners3.4_{i,t} + \beta_6 Partners5plus_{i,t} + \sum_{j=7}^{10} \beta_j X_{j,i,t} + \sum_{j=11}^{12} \beta_j Z_{j,i,t} + \eta_i + \lambda_t + \varepsilon_{i,t}$$

where $Y_{i,t+1}$, $TCoProm_{i,t}$ and $TInd_{i,t}$ represent the same as before, however, the term of interaction between the last two is removed as, in this new sample, no firm carries out different types of projects simultaneously. The remaining independent variables are:

- $Partners2_{i,t}$ – is a dummy variable that equals 1 if firm i partnered with two other entities in year t
- $Partners3.4_{i,t}$ – is a dummy variable that equals 1 if firm i partnered with three or four other entities in year t
- $Partners5plus_{i,t}$ – is a dummy variable that equals 1 if firm i partnered with five or more other entities in year t
- $X_{j,i,t}$ – represents the group of four ratios:
  $RProductivity_{i,t}$; $RExports_{i,t}$; $REmployment_{i,t}$; $RWageEmployee_{i,t}$.
- $Z_{j,i,t}$ – contains the effects attributed to the activity sector and the district of the firm:
  $ActivitySector_{i,t}$; $District_{i,t}$.

- η_i – captures the time-invariant characteristics of the firms
- λ_t– represents the effects from each period t
- $\varepsilon_{i,t}$ – represents the error term

Table 22 presents the results for the first estimation measuring the impacts of the consortiums on the outcomes variables.

Table 22 *- Consortium impacts on Productivity, Employment, Exports, and Sales (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.142***	0.133***	0.586**	0.289***
	(0.046)	(0.035)	(0.289)	(0.076)
TInd	0.016	0.114***	0.301***	0.119***
	(0.013)	(0.013)	(0.084)	(0.022)
Partners2	-0.142**	-0.052	-0.449	-0.318***
	(0.057)	(0.040)	(0.366)	(0.094)
Partners3.4	-0.078	-0.063	-1.004***	-0.262**
	(0.061)	(0.045)	(0.389)	(0.127)
Partners5plus	-0.135**	-0.058	-0.875***	-0.232***
	(0.053)	(0.042)	(0.331)	(0.087)
RProductivity	-0.011***	0.0004	0.002	-0.005
	(0.003)	(0.001)	(0.010)	(0.003)
RExports	-0.0000001	-0.000001**	-0.00001	-0.000002***
	(0.000001)	(0.000001)	(0.00001)	(0.000001)
REmployment	0.0001	0.00004**	-0.0003	0.0001**
	(0.0001)	(0.00002)	(0.0005)	(0.0001)
RWageEmployee	0.00002	0.0002	0.0002	-0.00003
	(0.0004)	(0.0001)	(0.001)	(0.0005)
Hausman Test	1182.8***	3172.7***	-	767.7***
Observations	34187	34187	34187	34187
Firms	3641	3641	3641	3641

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables. The Hausman Test for the Exports estimation developed an inconclusive result.
Source: Own computations using data provided by ANI merged with CB.

From the first set of results, it is possible to conclude that having fewer partners, in this case being part of the base group with just one partner, has more benefits. We observe all-around benefits attributed to the participation in copromotion projects that decrease for firms within projects with more than one other entity. However, it is not linear through all the estimations: regarding productivity, there are no

disadvantages connected to having 3 or 4 partners or having just 2 for the export's outcomes. These results may point to the theory that more entities involved within the same project might generate coordination problems and affect the effectiveness of the research, as stated by Crespi et al. (2020). The effects on employment are independent of the number of partners, as they do not differ depending on the dimension of the project in terms of members.

Looking for the dispersion measures, we only see an impact of these differences on the average worker productivity. The results point to a decrease in the productivity gains for firms that partner with more productive firms. The minimum value for the ratios is 0, but only for firms that do not undertake copromotion projects. For those who are engaged in such ventures, the minimum value is 1 (when we are dividing the most productive firm of the consortium by itself); thus, when that happens, ceteris paribus, the project in copromotion increases the productivity of the firm by 13% (0.142 – 0.011 x 100), however, the higher the ratio, the fewer gains are expected, for instance, if a firm is three times less productive than the most productive entity in the consortium, its expected gains are of 11%. These regressors might indicate that there is no diffusion of productive knowledge from the most productive firms to the lesser ones and that firms work better in partnerships when they are more similar in terms of the productivity of their workers. Some of the other ratios are statistically significant, although they have no economic significance.

As before, an evaluation of the same consortium's effects will now be presented, dividing the samples by firm size.

Table 23 *- Consortium impacts on Productivity, Employment, Exports, and Sales for Micro Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.245**	0.287***	0.545	0.478**
	(0.105)	(0.073)	(0.436)	(0.199)
TInd	0.043	0.167***	0.325**	0.160***
	(0.032)	(0.028)	(0.166)	(0.056)
Partners2	-0.273**	-0.068	-0.962	-0.752***
	(0.132)	(0.080)	(0.613)	(0.272)
Partners3.4	-0.062	-0.146	-0.802	-0.414
	(0.153)	(0.096)	(0.732)	(0.300)
Partners5plus	-0.159	-0.180**	-0.926*	-0.461*
	(0.130)	(0.087)	(0.555)	(0.244)
RProductivity	-0.010***	-0.001	0.008	-0.006*
	(0.004)	(0.001)	(0.006)	(0.003)
RExports	-0.000004***	0.0000001	0.00001	-0.000004**
	(0.000001)	(0.000001)	(0.00002)	(0.000002)
REmployment	0.0001	0.00004*	-0.0003	0.0002**
	(0.0001)	(0.00002)	(0.0004)	(0.0001)
RWageEmployee	-0.00004	0.0003***	-0.001	0.00001
	(0.0004)	(0.0001)	(0.001)	(0.0005)
Observations	12385	12385	12385	12385
Firms	1675	1675	1675	1675

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 24 *- Consortium impacts on Productivity, Employment, Exports, and Sales for Small Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.120*	0.029	0.950*	0.036
	(0.072)	(0.055)	(0.495)	(0.128)
TInd	0.000	0.098***	0.327**	0.118***
	(0.017)	(0.018)	(0.139)	(0.028)
Partners2	-0.079	0.036	0.007	-0.048
	(0.098)	(0.061)	(0.726)	(0.116)
Partners3.4	-0.060	-0.004	-1.621**	-0.041
	(0.086)	(0.065)	(0.641)	(0.125)
Partners5plus	-0.096	0.031	-0.976*	-0.145
	(0.080)	(0.071)	(0.581)	(0.116)
RProductivity	-0.019*	0.010*	-0.055	-0.012
	(0.012)	(0.006)	(0.049)	(0.011)
RExports	-0.000000003	-0.000001	-0.00001	-0.000002***
	(0.000001)	(0.000001)	(0.00001)	(0.000001)
REmployment	0.0002	-0.002***	-0.008	-0.002
	(0.001)	(0.001)	(0.009)	(0.002)
RWageEmployee	0.022	0.019	0.170	0.140*
	(0.021)	(0.013)	(0.107)	(0.084)
Observations	12902	12902	12902	12902
Firms	1195	1195	1195	1195

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 25 *- Consortium impacts on Productivity, Employment, Exports, and Sales for Medium Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	0.059*	0.063	-0.452	0.189**
	(0.035)	(0.054)	(0.587)	(0.093)
TInd	0.015	0.028	0.067	0.029
	(0.020)	(0.024)	(0.137)	(0.025)
Partners2	-0.063	-0.092	0.192	-0.213**
	(0.051)	(0.064)	(0.631)	(0.099)
Partners3.4	-0.084	-0.037	0.118	-0.429
	(0.059)	(0.077)	(0.668)	(0.275)
Partners5plus	-0.088*	-0.048	-0.006	-0.138
	(0.047)	(0.064)	(0.670)	(0.101)
RProductivity	0.013	-0.023**	0.013	-0.004
	(0.008)	(0.011)	(0.060)	(0.017)
RExports	0.000003**	0.00001***	-0.00001	0.00001***
	(0.000001)	(0.000002)	(0.00001)	(0.000002)
REmployment	0.0001	-0.0004	0.0004	-0.001
	(0.002)	(0.002)	(0.009)	(0.003)
RWageEmployee	-0.008	0.026	0.117	-0.00002
	(0.014)	(0.017)	(0.142)	(0.023)
Observations	6909	6909	6909	6909
Firms	602	602	602	602

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Table 26 *- Consortium impacts on Productivity, Employment, Exports, and Sales for Large Firms (Fixed-Effects)*

	Productivity	Employment	Exports	Sales
TCoProm	-0.118	-0.075	-0.027	-0.007
	(0.239)	(0.059)	(0.265)	(0.128)
TInd	-0.000	0.129**	0.071	0.119**
	(0.033)	(0.057)	(0.202)	(0.056)
Partners2	-0.053	0.015	0.587	-0.030
	(0.294)	(0.067)	(0.659)	(0.136)
Partners3.4	0.008	-0.166	-0.731	-0.397*
	(0.270)	(0.142)	(0.628)	(0.204)
Partners5plus	-0.052	0.016	-1.220	-0.097
	(0.253)	(0.067)	(0.744)	(0.144)
RProductivity	0.004	-0.036	0.251	-0.011
	(0.032)	(0.036)	(0.177)	(0.024)
RExports	0.00003	0.00004	0.002***	-0.000004
	(0.0001)	(0.0001)	(0.0002)	(0.0001)
REmployment	-0.012	0.028	0.331*	0.007
	(0.011)	(0.017)	(0.191)	(0.012)
RWageEmployee	-0.010	0.075	-0.499	0.031
	(0.053)	(0.058)	(0.340)	(0.033)
Observations	1991	1991	1991	1991
Firms	169	169	169	169

Notes. Robust standard errors clustered at the form level in parentheses. Significance levels: *, 10%; **, 5%; ***, 1%. Each dependent variable is in a logarithm. The model also includes the year, the activity sector, and the district as control variables.
Source: Own computations using data provided by ANI merged with CB.

Looking at Table 23 until Table 26, it is possible to notice that the composition of the consortiums mainly impacts smaller firms. As proof, the previously viewed negative impact of the productivity ratio is only statistically significant for micro and small firms (in the latter case, only at a 10% significance level). Even regarding the number of projects, the regressors are more significant for the smaller firms. Conversely, if we look at large firms, they benefit from partnering with bigger and more exporting firms, as it leads to increases in their exportations in the year following the completion of the project.

The results conclude that the consortium's composition is more impactful in smaller firms (mainly in micro), as having to partner with a higher number and more capable firms in terms of performance reduce their expected gains from projects in copromotion. The larger the firm, the smaller the impact the consortium has on the outcomes, and it may even have positive effects on the exports. These findings align with the statement of Alvarez & Barney (2001), who argues that small firms are harmed in their

performance by partnering with larger firms. However, the presented model only accounts for a simple diffusion measure, and it would be hasty to withdraw such a firm conclusion from a simplified model.

5 Concluding Remarks

This work studies the impacts of copromotion projects funded by public subsidies on firms' performance while distinguishing the effects by the different firm sizes. Another addressed dimension refers to the composition and characteristics of the partnerships and how they affect the outcomes of copromotion projects. This investigation benefits from using a very rich dataset, comprising project and firm-level information, for the period 2006-2019, of the population of firms that has ever applied for an R&D project, be it individually or in copromotion.

The first conclusion of our empirical analysis suggests that the applicants to copromotion projects are larger than the individual applicants. Concerning the copromotion candidates, our estimates show that firms that have their projects approved tend to be larger and more productive, corroborating the findings of Blanes & Busom (2004) and Aguiar & Gagnepain (2017).

Regarding the estimation of the impact on firms' performance, using a fixed-effects approach, the results point to positive effects of participating in copromotion projects on productivity, employment, and total sales. The analysis by firm size shows that smaller firms are the ones that benefit the most from participating in such projects, which is a finding in line with several works carried out thus far (see e.g. Feldman & Kelley, 2003; Cannone & Ughetto, 2014; Bronzini & Iachini, 2014; Bellucci et al., 2016; Cin et al., 2017; Santos, 2019; Crespi et al., 2020). Comparing the copromotion modality with the individual one, the first is more impactful in the firms' productivity. At the same time, the latter presents, in comparison, more benefits in terms of exports and sales. Alexandre (2021), in his study, concluded that, in Portugal, for a similar period, research joint ventures are associated with more benefits than individual projects. However, in this work, such superiority in all outcomes is only noticed for micro and small firms. The modality where firms carry out research projects alone presents, in comparison to joint projects, more gains for larger firms.

Our empirical estimates also show that the composition and characteristics of consortiums are crucial for the impact on the outcomes of smaller firms. In contrast, larger ones are not so affected by the number or type of engaged partners. The results suggest that the number of members in the partnership hurts the outcomes of the copromotion project. This result may be explained by management and coordination costs associated with bigger networks, which harm the project. The possible diffusion of knowledge through the association of different sized firms is not perceived in our estimations, with even some adverse effects arising, particularly in micro firms, by joining them with more productive firms. A possible explanation for these negative impacts might be related to coordination issues, where more similar firms

work together more efficiently. Another possible reasoning revolves around the argument of Alvarez & Barney (2001), which states that partnerships between small and large firms are not beneficial to the first. However, this issue deserves further investigation.

The results achieved in this work require further investigation as it presents several limitations. First, the models are lagged for only one period, and, as referred by Bayona-Sáez & García-Marco (2010), some projects might suffer from a delay period before their impacts become apparent in the firm performance. Hence, some effects might be overlooked by only using one lag period. The specification of the consortiums is also very simple, as it only accounts for the number of members and some dispersion measures. The presence of exporting firms, the cooperation with specific entities from the SCT (such as intermediary organisations or higher education institutions), and the geographic location of the partners may also be relevant to explain the possible impacts on the outcomes. With that said, it is not feasible to immediately conclude that partnerships between small and large firms are not optimal without further research. However, it is important to note that, as also supported by Bellucci et al. (2016), imposing partnerships between certain actors may not be the ideal approach, as trust is essential in such undertakings, mainly between small and large firms (Ring & Van de Ven, 1994; Child, 2001; Rothkegel et al., 2006). For future research, it would be interesting to deepen the effects of the consortiums and make a more in-depth evaluation of them by using other methodologies, such as matching procedures, to evaluate the different impacts of copromotion projects better.

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