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FIRMS' INNOVATION AND UNIVERSITY COOPERATION. NEW EVIDENCE FROM A SURVEY OF ITALIAN FIRMS

by Daniela Bragoli*, Flavia Cortelezzi** and Massimiliano Rigon***

Abstract

In this paper, we investigate whether cooperation with universities stimulates the innovative performance of Italian firms. We use a dataset merging information from two different surveys carried out by the Bank of Italy between 2007 and 2010. We derive our findings from a two-stage procedure in order to rule out any spurious correlations resulting from omitted variables. The results show that cooperation with universities does not affect the likelihood of firms introducing technological innovations. However, when we distinguish between pure technological innovation outcomes (only new products and/or productive processes) and joint innovation outcomes, which involve both organizational and technological changes, we find that only the latter are positively stimulated by cooperation with universities. These findings are promising since, according to the innovation management literature, joint innovation activities are more successful in translating new ideas and new business opportunities into market success.

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Contents

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1. Introduction[1]

Innovation activities are becoming more and more crucial for the economic survival of firms. Indeed, rapid technological changes, shorter product life cycles and globalization processes, have deeply transformed the competitive environment, making it necessary for firms to develop new products, to change productive processes or to implement new technologies (OECD, 2018). According to the literature on the knowledge-creating view of the firms, one possible channel to enhance innovation is increasing firms' access to external knowledge, to integrate and complement internal ideas and technologies with outside information (Cohen and Levinthal, 1990; Amesse and Cohendet, 2001; Chesbrough, 2003; Caloghirou et al., 2004). Within today's knowledge-based societies, universities play a crucial role since they represent an invaluable source of qualified knowledge, creating and disseminating new expertise and inventions, through basic and applied research (Jaffe, 1989; Mansfield, 1991; Mansfield and Lee, 1996; Etzkowitz and Leydesdorff, 1997; Mowery and Sampat, 2005).

In the mid-nineties the European Commission labelled as the "European Paradox" the perceived failure of European countries to translate scientific advances into marketable innovations (European Commission, 1995). The mismatch between the high level of scientific results achieved in research centers or universities and the low degree of competitiveness of firms in Europe, suggested that the interchange between firms and universities was superficial and should have been incentivized by policymakers. Since then, national governments and regional authorities tried to encourage technology transfer activities from universities to firms (see Kochenkova et al. 2016 for a survey on the role of governments in facilitating the commercialization of academic research and university–firm collaborations).

Economic theory recognizes a mutual benefit of the university-industry cooperation, but also tensions that may arise between the two institutions. Universities might be interested in the cooperation with firms to obtain funds for research assistance, lab equipment and their own research agenda and to obtain insights into their own research by being able to integrate theory with empirics (Hall, 2004). Similarly, firms might value their relationship with universities because there is some desire of risk sharing and because it gives them an early look-in at discoveries, they may not be able to anticipate (Lee, 2000). However, the specific characteristics of scientific knowledge, which involve technological innovations, make the

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cooperation between universities and firms for R&D projects difficult. This type of cooperation is in fact characterized by high uncertainty, high information asymmetries between partners, high transaction costs for knowledge exchange, requiring the presence of absorptive capacity at each side of the market transfer and high spillovers to other market actors (Hall, 2004; Hall et al. 2001, 2003; Cassiman and Veugelers, 2005). It follows that there is not a full agreement on the effects of university-industry cooperation; whether more innovative firms are more prone to cooperate with external partners and whether this cooperation is beneficial for technological innovation is not well defined even in the empirical literature.[2]

Our work is related to this strand of empirical papers with some novel aspects. First, we analyse the behaviour of Italian firms. The case of Italy is interesting since, as discussed in Bugamelli et al. (2012), starting from the '90 the productivity of Italian firms has slowed down compared to other advanced economies and the technological gap has widened given the low propensity of Italian firms to innovate. The literature on the topic has identified three main drivers to the gap: the specialization in traditional sectors, the firms' governance, often based on family control, and firms' size.[3] The latter, which is strongly linked to the others, makes it very hard for Italian firms to specialize in high and intensive knowledge sectors, which are characterized by relevant economies of scale, oligopolistic competition and by amounts of investments which are larger than those typical of Italian firms.[4] Small and medium Italian firms usually do not have internal research labs and finance their R&D activities through internal funds (Bragoli et al. 2016; Bragoli et al. 2020; Barbieri et al. 2020). It follows that the cooperation with other firms and with universities or research centers could become crucial in order to bridge – at least partially – the technological gap of Italian firms with foreign competitors.[5] The contributions on university-industry cooperation are summarized for the Italian case in Grimaldi et al. (2021) for what concerns regional specialization, whereas Bellandi et al. (2021) put forward an interpretative framework that links central entrepreneurial or engaged strategies with the way academics organize their third mission activities. Other studies, concentrating on the specificities of the Italian industrial

[2] See for example literature on complementarity and substitution between internal and external sourcing (Cassiman and Veugelers, 2002; Cassiman and Veugelers, 2005).

[3] In Italy, the fragmentation of the production system is greater than in all the other major advanced economies. In terms of added value and employment, companies with less than 250 employees represent, respectively, about 70% and 80% of the total, more than 10 percentage points higher than the average of the European Union countries (European Commission, 2017).

[4] A different stream of the literature has emphasized some positive aspects of the Italian production system, showing that Italian small and medium-sized enterprises, especially manufacturing companies that have been able to exploit agglomeration economies in the bright activity of industrial districts, have themselves been the actors of a success story that has combined growth and innovation for a long time. In spite of the strong competition of less developed countries, Industrial Districts firms have been able to strongly differentiate and increase the added value of their products (Sforzi, 2009 and Marseguerra et al. 2016).

[5] Using data on 1,500 regions across 78 countries from 1950 and 2010, Valero and Van Reneen (2019) find that increases in the number of universities are positively associated with future growth of GDP per capita. Part of the effect of universities on growth is mediated through an increased supply of human capital and greater innovation.

sector, focus on sectoral effects on the patterns of cooperation, especially in low-tech regions (Parmentola et al., 2021; Maietta, 2015; Giuliani and Arza, 2009).[6]

Secondly, we distinguish between different types of innovation outputs since the OECD and Eurostat have found the need of diversifying between technological and other types of innovation, introducing also organizational and marketing innovations into the guidelines for collecting and interpreting innovation data (Oslo-Manual, OECD and Eurostat 2005). The rationale of this distinction stems from the fact that technological innovation has been criticized for not fully capturing innovation in services and for ignoring important elements of innovative activities of firms, such as the adoption of new practices and the re-organization of existing business routines, external relations, and marketing (Hipp and Grupp 2005; Baranano, 2003; Boer and During, 2001).

In particular, the aim of this paper is not only to provide evidence on whether cooperation with universities encourages innovation, but also to investigate what type of innovation output cooperation with universities targets. We distinguish between three different types of innovation: pure organizational, pure technological (new products or productive processes) and joint innovation which occurs when firms introduce both organizational and technological changes. The conceptual framework which motivates our analysis is linked to the idea of entrepreneurial university (see Cerver Romero et al., 2021 for a recent review), according to which the role of universities has evolved considerably over time from an entity producing 'knowledge for its own sake' to being a source of knowledge that is requisite for economic growth. Within this framework the role of universities goes beyond generating technology transfer, rather the mandate of the university in the entrepreneurial society is to contribute and provide leadership for creating entrepreneurial thinking, actions, institutions and what Audretsch et al. (2006) refer to as entrepreneurship capital. Universities encourage not only technological transfer but also knowledge transfer, making the innovation process more pervasive in nature involving different forms of activities and not only the more traditional purely technological type.

Empirically most papers on the firm-university cooperation focus on the effects on technological innovation, however there is a vast literature - sometimes labelled as "innovation management literature" - that points out different reasons why joint innovation is relevant (see Damanpour, 2020). The first relates to the fact that investing in both types of innovation activities is very common, since some kinds of innovations

[6] Other studies on the Italian case include Medda et al. (2006) focus on the impact research cooperation on TFP growth. Hall et al. (2013) use different waves of the "Survey on manufacturing firms" conducted by the Italian commercial bank Unicredit to investigate the impact on R&D and ICT investment on innovation and productivity of Italian firms. Differently from our paper, they focus on internal resources of firms and do not analyse the interaction with universities.

do not have exclusively a technological or organizational content. Innovations influence each other and hence, they ought to be implemented in conjunction (Hervas-Olivier et al. 2012; Johannessen et al., 2001; Drejer, 2002; Garcia and Calantone, 2002). Secondly, the presence of a joint strategy, which goes beyond the introduction of new products and services but also pervades the whole economic system, involving also new business and management models, might be related to a type of innovation that requires a more intense change, for which the complementarities between university and firms could be stronger (Ringberg et al., 2019). As a third aspect, the innovation management literature stresses the importance of integrating both types of innovative activities for successfully transferring new ideas and new business opportunities into market success (Tidd et al., 2001; Cozzarin and Percival, 2006 and 2008; Evangelista and Vezzani, 2010).

We depart from most of other papers on the topic, which rely on multivariate binary models and simultaneous equations to account for reverse causality. In contrast, we use a two-stage econometric strategy. More precisely, since the model is nonlinear, we derive our results using a 'two-stage residual inclusion' procedure as in Terza et al. (2008) and Wooldridge (2014 and 2015).[7] To rule out spurious correlations, due to the possible existence of omitted variables, we use as exclusion restriction in the first stage a variable which combines the distance between firms and universities with a measure of universities' openness to external cooperation.

We use a unique Italian firm level database merging two different datasets, which contain data on Italian firms with more than 19 employees collected by the Bank of Italy through two different surveys: the Survey of industrial and service firms and the Bank of Italy's Business Outlook Survey of industrial and service firms. Results show that the cooperation with universities increases the probability of a joint innovation activity, while we do not find any significant effect when we consider a broader definition of technological innovation which encompasses both pure technological and joint innovation. This finding implies that universities become crucial when the innovation is not only the creation of a new product or productive process, but when it also introduces changes that pertain to different spheres of the firms' activities bringing it closer, to some extent, to the Schumpeterian concept of disruptive innovation. This is good news since, according to the innovation management literature, these innovations can be more easily translated into market success. It worth noticing that the last available dataset provided by the Innovation Community Survey (CIS) shows that the share of innovative firms collaborating with universities or public

[7] When we consider the binary outcome (according to the introduction or not of a technological innovation) we also estimate a linear probability model to compare the results with those obtained with the residual inclusion technique, as described in the section 4.

research centers is still low[8]. Therefore, despite of the fact that our results refers to the past decade, they still contain valid policy implications: the firm-university cooperation should be encouraged to stimulate successful innovation and increase the productivity of Italian firms, thus reducing the technological gap with their competitors.

The rest of the paper is organized as follows. Section 2 outlines the literature review on the topic; Section 3 provides an overview of the data and delineates the variable selection process; Section 4 describes the econometric strategy; Section 5 contains the main results; finally, Section 6 concludes.

2. Literature Review

The literature that we review in this Section can be divided in two main strands. One is mainly interested in studying the complementarity/substitution between internal and external sources of knowledge, the other is instead mainly focused in analysing the effect of external cooperation on innovation.

According to the first stream, whether outside sources of knowledge are important for the firm to generate innovation depends on how the external knowledge interacts with its internal capabilities, i.e., with the accumulated knowledge and skills that enable the firm to coordinate its activities and deploy resources advantageously.

An extensive theoretical literature in Industrial Organization has developed around the effects of external spillovers on own R&D (see De Bondt, 1996 for a review). According to some contributions, which focus on R&D spillovers among firms, not only external R&D will typically substitute for own R&D in the receiving firm, but spillovers will also reduce own R&D by the sending firm, since the latter cannot fully internalize all benefits from its investment (Spence, 1984). To the contrary, according to other studies, a firm's ability to identify, assimilate and exploit existing external technologies can be enhanced by own R&D (e.g., Harabi, 1995). The notion of absorptive capacity introduced by Cohen and Levinthal (1990) stresses the importance of a stock of prior knowledge to effectively absorb spillovers. In this last setting, the desire to assimilate external know-how creates a positive incentive to invest in R&D. Hence spillovers, rather than diminish own R&D, may encourage industry R&D investments.

The empirical literature that follows this first stream has taken different directions. Some studies address the relation between internal and external R&D investigating the role of R&D cooperation with external partners (Veugelers, 1997; Cassiman and Veugelers, 2002; Cassiman and Veugelers, 2005), such as

[8] According to the CIS 2018 (the last publicly available) the share of Italian innovative firms (as defined in the Oslo manual 2018, whose definition of innovation is broader than the one used in our paper) increased over the 50% mark; however only about 11% of these innovative firms collaborated with universities or research centers

other firms (Arvanitis et al., 2020) or research institutes/universities (Becker, 2003, Becker and Dietz, 2004) and look at the role of complementarity and substitution between internal and external sources of knowledge.

Focusing on the firm-university cooperation, some studies find a complementarity between internal and external sources of knowledge. Becker (2003) shows that, through cooperation, firms improve their technological know-how and internal skills, which increase firms' internal capabilities for developing new products and technologies.

Becker and Dietz (2004) investigate the complementarities between internal and external R&D, studying the effect of R&D cooperation on firms' innovation. They find that R&D cooperation is used to complement internal resources in the innovation process, enhancing the innovation input and output measured by the intensity of in-house R&D and by the realization of product innovations. Along the same line, Gómez et al. (2020) show that extramural investments in R&D play a key role in assuring that firms increase their proportion of high novelty products, whereas they are less relevant when dealing with low novelty products.

However, not all studies find a positive relationship between R&D cooperation and firms' innovation performance. These findings are motivated by a substitutive relationship between specific innovation activities or knowledge sources, which may be explained in the context of path dependencies, switching costs and/or diseconomies of scope (Hagedoorn and Wang, 2012). Some scholars provide empirical evidence on offsetting (or non-synergistic effects) of internal and external knowledge sources on firm innovation (Berchicci, 2013; Laursen and Salter, 2006; Vega-Jurado et al. 2009). More recently, Caloghirou et al. (2021) show an inverted U-shaped relationship between industry-university cooperation and product innovation and show that knowledge stocks (internal capabilities) moderate the relationship between industry-university collaboration and product innovation, suggesting that firms with low levels of knowledge stocks (age, export and employee's educational level) benefit more in terms of innovation from the development of knowledge flows with universities.

The second stream of the literature analyses the relationship between firm-university cooperation and innovation, disregarding the interaction between internal and external sources of knowledge. Indeed, these studies are mainly interested in measuring the additional effects of firm-university cooperation on firms' innovative inputs, outputs or more generally on firm performance, controlling for firms' internal capabilities.

Regarding the effects of university cooperation on firms' innovation output, the first papers that address the issue empirically are those of Jaffe (1989) and Mansfield (1995), both related to the US. The latter shows that in a random sample of 76 large American firms belonging to seven manufacturing industries, about 10% of the product and process innovations could not have been developed without recent academic research. As in Mansfield (1995), most of the papers identify as innovation the introduction of a new product or a new productive process. Empirical evidence has been provided for firms in different countries and results are mixed. Some papers find positive effects on firms' innovative activities, including R&D intensity (Scandura, 2016), the propensity to register new patents as well as the introduction and sales of new products (Arvanitis et al., 2008; Fritsch and Franke, 2004; Aschhoff and Schmidt, 2008). For others, the results are less clear-cut. Monjon and Waelbroeck (2003) find that cooperation with foreign universities increases the probability of radical innovation. Rouvinen (2002), focusing on Finnish firms, shows that cooperation with universities has a positive impact on product innovation, but no impact on process innovation. Robin and Schubert (2013) find similar results for France and Germany. Lööf and Broström (2008), using Community Innovation Survey (CIS) data on Swedish firms, show that university collaboration positively influences product innovation sales as well as the propensity to apply for patent for manufacturing firms with 100 or more employees, whereas they find no effect for firms in the service sector.

Analysing the impact of university cooperation on the economic performance of firms (i.e. labor productivity, total factor productivity), Medda et al. (2006) do not find any significant effect of collaborative research undertaken by Italian manufacturing firms and universities on total factor productivity growth, whereas other studies find a positive effect on several measures of labor productivity, sales productivity or sales growth (see e.g. Belderbos et al., 2004; Branstetter and Ogura, 2005).

More recently the literature has focused on the role of entrepreneurial university (see Cerver Romero et al., 2021 for a recent review). According to Audretsch (2014) the role of universities has evolved considerably over time from an entity producing 'knowledge for its own sake' to being a source of knowledge that is requisite for economic growth. The emergence of the entrepreneurial university gave universities a dual mandate, i.e. to produce new knowledge but also to facilitate the transfer of technology and knowledge spillovers (Acs et al., 2009; Audretsch, 2014; Link and Sarala, 2019). Universities, through third mission activities, act as agents for stimulating economic growth and development (Rippa and Secundo, 2019) creating new learning environments and representing a context for knowledge spillover creation. Secundo et al. (2021) investigate the role of knowledge spillover entrepreneurship analysing the process of intentional and unintentional knowledge flows among universities, industries, and institutions. Aksoy et al. (2022) base their analysis on the type of knowledge that may influence the success rate of knowledge transfer. In particular, the diversity of the knowledge base and cognitive proximity between partners are found to be important for this purpose.

This recent literature in studying the relation between university and firms has moved away from the notion of 'technology transfer' towards the idea of 'knowledge transfer' which, in turn, is being challenged by the concept of the more free-flowing multidimensional 'knowledge exchange' between the three sectors of the 'triple helix', comprising universities, business and the government (Trencher et al., 2014).

Within this context the role of universities goes beyond generating technology transfer, rather the mandate of the university in the entrepreneurial society is to contribute and provide leadership for creating entrepreneurial thinking, actions, institutions and what Audretsch et al. (2006) refer to as entrepreneurship capital.

Building around the conceptual framework of knowledge transfer in this paper we study the role of university firm cooperation distinguishing between pure technological innovation (new products and/or new productive process), organizational innovation and the joint innovation activity. From our analysis we expect that, since universities encourage knowledge transfer together with technological transfer, the most probable form of innovative activity promoted by cooperation should thus be the presence of both technological and organizational innovation, i.e. joint innovation.

In the following subsection, we present the literature, which focuses on the distinction between technological, organizational, and joint innovation.

2.1 Technological and Organizational innovation: the importance of combining them.

Many researchers have used the term innovation to identify technology-based product and process innovations (see Crossan and Apaydin, 2010 for a review). However, while the importance of technology and technological innovation for firms is undeniable, the concept of innovation is broader, and technological innovation is only one type of innovation that firms generate or adopt (Damanpour, 2020).

The distinction between the different types of innovations dates to Schumpeter, which identifies five different types: new products, new methods of production, new markets, new sources of supply, and new ways to organize businesses. More recently Meeus and Edquist (2006) distinguish between two types of product innovations (innovation in goods and services) and two types of process innovations (technological process and organizational). Tether and Tajar (2008) base their analysis on three dimensions of change: 1) changes to what the firm produces versus changes to how the firm operates, 2) changes to physical technologies versus changes to social technologies, 3) the locus of change, intrafirm versus interfirm. Damanpour (2020) follows the same classification as in Tether and Tajar (2008) but adds a new dimension distinguishing between radical versus incremental innovation.

It is useful to distinguish between different types of innovation since, although each innovation has different characteristics, all of them contribute to firms' performance. Technological innovations are directly related to the main activities of the firm, whereas organizational affect mainly its management systems (Daft, 1978; Damanpour & Evan, 1984). They are processes and practices that modify the way management is conducted and constitute the rules and routines through which tasks are organized within the firm (Birkinshaw et al., 2008; Hamel, 2006). The concept of organizational innovation is complex and difficult to measure. In a literature review, Černe et al. (2016) identify several non-technological innovations including organizational innovation.

In general, while organizational (non-technological process) innovations are recognized as relevant (Arrow, 1962; Sanidas, 2005), and their introduction is considered necessary to renew organizational strategy, structure, and systems (Nickell et al., 2001; Birkinshaw et al., 2008; Volberda et al., 2013), research on this type of innovation lags behind technological innovation, and its effect on performance is considered to be less evident.[9] Theoretical arguments, however, claim that the combination of the two types of innovation is more effective in terms of performance outcome rather than the single innovative activities.

According to some authors (Damanpour et al., 2009; Roberts and Amit, 2003), innovative performance calls for the introduction of different types of innovations to help adapt organizations to external and internal changes. Innovation types are related to one another, the introduction of one type could favor the introduction of another, and an understanding of the contributions of each type requires an understanding of its relations with the other types (Damanpour, 2020).

Georgantzas and Shapiro (1993) define 'synchronous innovation' the adoption of congruous technological and organizational innovations. They examine the influence of synchronous innovation on performance and find that the independent effect of each innovation type on performance is very small without synchronous innovation. Roberts and Amit (2003), analysing the effect of three types of innovations (product, process, and distribution) on performance in retail banking organizations, find that long-term performance depends on the history of firms innovation activity rather than on the occasional positive result of single innovations (Roberts and Amit, 2003).

Empirical evidence from these studies challenges the notion that firm performance is promoted by the success of a specific type of innovation, whether product, service, process, technical, or managerial.

[9] Walker et al 2015 integrated the empirical findings from 44 articles published in peer-reviewed journals and found that the adoption of organizational innovations positively affects organizational performance. A comparison of a matched sample of associations of technological and managerial innovations with organizational performance showed that the two types of innovations affect performance similarly.

Instead, they suggest that performance requires harmonious adjustments of various organizational subsystems through the introduction of complementary innovation types (Ballot et al. 2015; Battisti and Iona, 2009; Hervas-Oliver and Sempere-Ripoll, 2014; Naranjo-Gil, 2009). Ringberg et al. (2019) find that joint technological and organizational innovation might involve a more intense change. Some papers have pointed out that the effects of a joint innovation are usually more successful in transferring new ideas and new business opportunities into market success (Tidd et al., 2001; Cozzarin, 2017; Cozzarin and Perzival, 2006 and 2008; Evangelista and Vezzani, 2010).

A possible reason for this is related to the fact that the two innovative strategies (technological and organizational) might be complementary and thus increase the complexity within the firm that, together with internal routines, creates a competitive advantage because the use of a complex strategy may act as a barrier to potential imitators (Rivkin, 2000).

It follows that organizational innovation, by affecting technological innovation positively (Schmidt and Rammer, 2007; Bartoloni and Baussola, 2018), may have an impact on firms' productivity and profitability.

3. Data

3.1 Data Sources

The dataset used in the analysis is the joint result of two different surveys carried out by the Bank of Italy: the Bank of Italy's Survey of industrial and service firms (Invind, hereafter) and the Bank of Italy's Business Outlook Survey of industrial and service firms.[10]

Invind represents one of the richest sources of information at the firm level for Italy. It is carried out by the Bank of Italy once a year between March and April since 1984. It collects both quantitative and qualitative information about industrial and service firms. Similarly, the Business Outlook is carried out once a year, between September and October since 1993, on the same sample of firms interviewed with Invind. Information is collected through telephone interviews. In both cases interviewers are officials of the Bank

[10] The database Invind goes back to 1984. The questionnaire is sent to each enterprise at the beginning of each year and the questions refer to the last two years (this allows data consistency to be checked over time). The sample is stratified according to three criteria: sector of economic activity, size and geographical location. The presence of outliers and missing data within the sample is dealt with by means of appropriate statistical techniques. The Business Outlook is similar to Invind but it contains less questions and is more focused on the business cycle.

of Italy, who tend to establish long-run relationships with firms' managers and are also responsible for the accuracy of the collected information.

Both surveys contain questions that are fixed over time, mainly concerning sales, employment and investments, and a series of questions that vary each year according to the specific issues investigated. For this reason, we focus on the 2007 release of the Business Outlook and on the 2010 release of Invind.[11] The former contains a section focusing on the cooperation between firms and universities, while in Invind there are some questions on the innovative attitude of firms. In 2007, the Business Outlook collected answers of 4,196 firms, while Invind with the 2010 release interviews 3,937 firms. Unfortunately, in the 2010 release, questions on innovative attitudes were asked to a random subsample of half of the firms. For this reason, the number of available information drop to 1,964. Due to the presence of missing observations, when we merge the two datasets, we end up with a sample of 1,125 firms, which is the dataset used in our empirical investigation. The Bank of Italy surveys have two main advantages. First, they contain high quality data, mainly due to the rigorous procedure followed in the collection. Second, the surveys mainly focus on medium and large firms, which are the most innovative.[12]

3.2 Organizational, Technological, Joint Innovation

In this paper, the firm's innovative strategy is measured using Invind 2010 question, which asks firms whether, between 2008 and 2010, they were successfully involved in one or more of the following activities: product innovations, innovation of productive processes, managerial or organizational innovations. Firms' tasks that involved only managerial or organizational changes are defined as organizational, firms' activities that involved only product and/or process and both product/process are defined as technological, finally firms' activities which involve both technological and organizational innovation are defined as joint. Thus, we use this information to define the dependent variables to investigate the role of university cooperation. Therefore, this paper is mainly focused on technological innovations, distinguishing between those that have been introduced together with organizational changes from those that have not required changes in the

[11] A more recent version of the dataset was not possible to consider since only those releases contain the information needed to conduct the analysis on the relation between university-firm cooperation and innovation. Although in the last ten years the relationship between universities and firms may have evolved, we feel that the dataset can still be effectively used to capture the causal relationship between the cooperation with universities and the innovation strategies of firms. The issue we address has in fact a long-run (structural) nature.

[12] In this paper we do not consider young innovative companies and start-ups. These firms are usually very small and risky. They are focused on the development and the implementation of new technologies, and they deserve and *ad hoc* analysis (see, e.g., Pellegrino et al., 2012).

organization of the firms. We use three different definitions of dependent variable. Two are dummy variables. The first takes value equal to 1 when the firm has introduced a technological innovation (either pure or joint) and zero otherwise; alternatively, we define the dependent variable distinguishing the firms that adopted a joint innovation strategy from the others. Finally, we construct a factor variable, which can take four different values (0=*no innovation*, 1=*pure organizational*, 2=*pure technological*, 3= *joint*), with the aim of studying whether the firm university cooperation targets a specific type of innovation activity.

3.3 Cooperation with Universities

The main regressor captures the collaboration between the firm and academic institutions. The variable is based on two questions contained in the 2007 release of the Business Outlook. Firms are asked whether they collaborate with one or more universities and in case of positive answer whether the collaboration agreement involves 1) the financing of R&D projects or cooperation in a research project; 2) the purchase of consulting services; 3) a university students' internship in the firm.

We use the answers to these questions to build a binary variable (*university*), which takes the value equal to 1, when the cooperation between firms and universities involves the purchase of consulting services or the financing of R&D projects. When firms and universities do not cooperate or when the collaboration implies only student internships in the firms, then the variable university takes value equal to 0. We make this choice because we expect that the innovation activity is the outcome of a close interaction between firms and universities; in contrast, 'soft' types of cooperation, such as students' internships, most likely will not provide useful contribution to firms' innovation.

3.4 Control variables

We introduce several controls to account for different firms' characteristics and to reduce the omitted variable bias. Table A1 in the appendix shows the complete list of the variables used in the analysis. For the sake of clarity, we group these variables in three vectors. Vector B includes balance sheet variables, namely sales and investments. These variables are computed as the average value of the three years preceding the collaboration period investigated in the survey and they enter the model in natural logarithms. The vector F includes other information related to firms: size (*size*) measured by the number of employees (thousands of units); age (*age*), which considers the number of years since the firm was founded; *group* is a factor variable, which takes values 0 if the firm does not belong to a group, value 1 if the firm is part of an Italian group and value 2 if the group has a foreign ownership; *export* is a categorical variable, which classifies firms in four different groups: non-exporting firms and firms whose share of sales due to exportations is less than 1/3, between 1/3 and 2/3 and more than 2/3.[13] The variable *bluecollar* is given by the average share of blue-collar workers over total employees; finally the *dummy district* identifies whether the firm is located in one of the industrial districts defined by the Italian Institute of Statistics.[14]

The vector I includes two dummies, which should capture the firm's internal capabilities. The variable *research center* takes value equal to 1 if the firm has a research center (either in Italy or abroad) and zero otherwise, while the dummy *R&D* distinguishes firms that invest in internal R&D from the others. As shown in Table A2, all these variables are highly correlated with the cooperation dummy confirming the results in the literature, according to which firms are more likely to access to external source of knowledge when they are more able to internalize their positive spillovers.

Finally, we include *sectoral* and *geographical* dummies to consider fixed effects related both to the sector of economic activity of the firm and to its geographical (regional) location.

3.5 Instruments

It is worth noticing that, since collaboration is observed in the period 2005-07, before the innovation is realized (2008-2010), we are sure that our estimates do not suffer from the reverse causality problem. In addition, we must consider that usually there is a systematic delay between the beginning of the collaboration and the observation of the results. Therefore, combining two different releases of Invind and Business Outlook, we can track how collaboration between 2005 and 2007 influences the achievement of innovation in the following three-year period.

However, there is still a possible bias due to omitted variables. The expected sign of the bias is not clear. On the one hand, the estimates could be upward biased since most of the reasons that induce firms to collaborate with universities may be also relevant to explain their innovation activity. On the other hand, more innovative firms may not want to cooperate with universities, since the latter may involve transaction costs and appropriability issues.

To consider possible confounding effects, we have introduced several controls. Some controls are suitable to capture the internal capabilities of the firms i.e., the presence of a research center within the firm

13 We have also considered the case in which firms are distinguished in only two groups, exporting and non-exporting firms, respectively. Results, not shown in the paper, are substantially unchanged.
14 A more detailed description of the Italian Industrial districts is provided in the Istat web page: https://www.istat.it/en/archivio/150367

or the group, and the firm's spending in R&D. Still, we cannot be sure that we have eliminated all the possible endogeneity in the model. Our strategy to tackle the endogeneity issue is to identify an exogenous variable which directly influences firms' cooperation with universities, but, at the same time, it does not directly affect the innovation strategy.

To our knowledge, in the economic literature, suggestions about a suitable instrument for the firm-university cooperation seem to be missing. We think that the geographical distance between the firm and the nearest university could be a good instrument for our purpose. Geographical proximity plays a fundamental role as a determinant of the firm-university collaboration, since firms that are located near universities may frequently collaborate with them and benefit from knowledge spillovers (D'Este et al., 2013). Geographical proximity enables the transmission of tacit knowledge, which is personal and context-dependent; it cannot be easily bought via the market, and it is difficult to communicate other than through personal interaction in the context of shared experiences (Morgan, 2004). Geographical proximity matters when knowledge spillovers are informal and in the event of information asymmetry between researchers and research users, which arises when users cannot precisely evaluate the applicability of the transferred research until they attempt to translate it into new or improved products or processes (Audretsch and Feldman, 1996; Landry et al., 2007). In the context of asymmetry, the transfer of knowledge is unlikely if researchers and research users do not have frequent interactions. The number of universities within the region in which a firm is located also affects the probability of interacting with a nearby university because it increases the range of options that are available to a firm (D'Este and Iammarino, 2010).

Fantino et al. (2015) show that in Italy the distance affects the probability of collaboration between firms and universities. Their results are in line with other studies on the role of firm-university geographical proximity (see, for example, Laursen et al., 2008 and Hewitt-Dundas, 2013). Maietta (2015), focusing on the Italian food and drink industry, finds that the probability of cooperation between firms and universities reduces as their distance increases.

In our paper, we compute the geodesic distance between the Italian universities and all firms in the Invind archive. We consider the firm's address and in the case of universities with two or more campuses we consider the distance between each firm and all the university's campuses. However, we are aware that it is possible that the distance itself can be considered endogenous, depending on the firm's location choice: firms can decide to locate close to a university if they are likely to cooperate with that university. Indeed, most of Italian universities are older than firms in our sample. Although this endogeneity problem might still be present, we think that it is more relevant for start-ups, which may be universities spin-offs and are generally founded by researchers or in collaboration with researchers of the same university. Our sample focuses on firms with at least 20 employees and start-ups are not included in the analysis. Nevertheless, to reduce the likelihood that the restriction used in the first stage might be loosely endogenous, we combine the geographical distance with a measure of university openness to external collaboration. For this purpose, we use the results of the first Anvur[15] report on the so-called 'third mission', which contains eight different indicators used to assess the ability of universities to interact with the territory (environment, firms, population). In our paper we construct a synthetic index, which aggregates for each university the eight different scores. We think that the index is the most suitable measure of the quality of university interactions with external partners, both private firms and public institutions and we prefer it to other measures of research quality which have been used for example by D' Este and Iammarino (2010) for the UK and by Maietta (2015) for Italy.[16]

Importantly, the ranking of the university according to this index was completely unknown to firms since the first release was carried out in 2011 and related to the period 2004-2010. According to the Anvur assessment, universities with a higher degree of openness to external collaboration have a higher value of the overall index; we rescale the index to range between zero and one and we use this measure to weight the firm-university distance as follows:

weighted distance=distance (km)*(1+anvur_index)

We use the variable *weighted distance* to build our instrumental variable which is binary (*dummy weighted distance*) and takes value equal to 0 if the variable *weighted distance* is below the median and 1 otherwise. We consider the weighted distance between each firm and the nearest university and we compute a different median for each geographical area of the firm headquarters (North, Centre and South, defined according to the Istat classification).[17] The variable *dummy weighted distance* as defined above is used as a restriction in the first stage.

[15] The Anvur is the Italian National Agency for the Evaluation of University and Research Center.

[16] D'Este and Iammarino (2010) find that research quality bears an influence on the frequency of collaborations between university departments and firms in the UK. Similarly, Maietta (2015) uses the quality research assessment of Italian university (VQR) to evaluate the quality of agricultural studies faculty for Italian universities.

[17] The median value of the geodesic distance between the firm and the nearest university in the sample is about 17.1 km in the North, 18.8 Km in the Centre and 20.7 Km in the South.

3.6 Descriptive statistics

According to Table 1, 62.4% of firms in our sample introduce an innovation between 2008 and 2010. However, only 22.3% cooperate with universities actively as consultants or partners in a joint research program. Of the cooperating firms, 20.3% do not innovate, 4.8% introduce only organizational innovation, 21.1% introduce only technological innovation and 53.8% introduce both.

Innovation activity and the interaction with universities Table 1

	No innovation	Organizational	Pure Technological	Joint innovation	Total
No Cooperation with university	372	76	151	275	874
Cooperation with university	51	12	53	135	251
Total	423	88	204	410	1,125

Source: authors' calculations

Considering that we are not including small firms, these figures are substantially in line with the statistics based on the Community Innovation Survey (CIS) provided by the Italian Institute of Statistics (Istat) and confirms that our sample is not a biased representation of Italian firms.[18] It is worth noting that among firms that adopt a technological innovation (both pure and joint) the share of firms that introduce a joint innovation is higher for cooperative firms.

Technological innovation Table 2

	Pure technological innovation	Joint innovation	Total
Only new products	90	56	146
Only new productive processes	35	45	80
New products and new productive processes	79	309	388
Total	204	410	614

Source: authors' calculations

[18] According to the CIS, between 2008 and 2012 about one third of Italian firms introduced a substantial innovation in the productive process or realized an innovative good or service. However, in the same period less than 10% of interviewed firms collaborated with at least one university or other higher education institutions. In the group of firms that collaborated with universities the share of those that introduced an innovation in the productive process or a new product was much higher compared to the rest of the sample (see ISTAT 2012; data are freely available from the Istat website).

According to Table 2, in about 75% of firms with a joint innovation, the technological change involves both a new product and a new productive process; this share is much lower in pure technologically innovative firms (about 39%) which have more frequently introduced new products.

Table A3 in the appendix shows some descriptive statistics for these four groups of firms. We note that those that realized a joint innovation differ from the others, while those that introduce a pure organizational or technological innovation are on average quite similar in many respects. Broadly speaking, firms that realized a joint innovation are generally older and larger with respect to other firms in the sample. As expected, they invest more and their share of bluecollar workers over total employees is lower with respect to other firms.

The percentage of firms that export a significant share of their products is higher among technologically innovative firms, which is consistent with the results of other studies for Italy (Basile, 2001; Accetturo et al., 2014), since the propensity to export is highly correlated with the competitive attitude of firms. There is a consensus on the fact that firms which innovate are more likely to access international markets and export (see, e.g., Love and Roper, 2002; Becker and Egger, 2013). Moreover, the percentage of firms with a joint innovation is slightly higher when we look at groups of firms. Not surprisingly the variables used as proxies of firms' internal capabilities - namely the presence of a research centre (within the firm or the group) and internal R&D spending - are more widespread among these innovative firms. The share of firms that realized a technological innovation is higher in the North-West of Italy, which is also the area with higher per capita income; in contrast, the percentage of non-innovative firms is larger in the South of Italy, which is the less developed part of the country. [19] When we look at Industrial districts, as defined by Istat, we find that a higher share of district firms have realized a technological or joint innovation compared to non-district firms.[20]

Finally, firms with a technological innovation are more concentrated in the manufacturing industry, in sectors related to engineering and chemistry; in contrast, in the service sector the share of innovative firms is much lower. We think that the dichotomy is only partially related to the characteristics of the sectors. Services provide generally more labor intensive and non-tradable products, which reduce firms' incentives

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[19] North-West includes the following Regions: Lombardia, Piemonte, Valle d'Aosta and Liguria; North-East includes: Veneto, Trentino Alto Adige, Friuli Venezia Giulia and Emilia Romagna, Centre includes: Toscana, Lazio; Umbria, Marche; South incudes: Abruzzo, Molise, Campania, Puglia, Basilicata, Calabria, Sicilia and Sardegna.

[20] Istat identifies the Industrial district on the basis of "labor market areas" and the analysis of their economic specialization using the data on economic units obtained by the Industry and Services Census. In this paper we use the 2011 release by the Istat based on the 9th Industry and Services Census. The number of business clusters has decreased by 40 units with respect to the previous release (2001).

to conduct technological change. However, it also reflects a feature of the Italian economy: with respect to other advanced economies, in Italy the manufacturing industry accounts for a higher percentage of national GDP, while there is a lag in the growth of innovative services to firms (Bugamelli et al., 2018).

4. Empirical strategy

The main issue we need to address is the potential endogeneity of the variable *university*. The estimation of a non-linear model with a potentially endogenous discrete variable is a difficult task. In this paper we address this issue using the control function approach as suggested by Wooldridge (2014 and 2015). Wooldridge (2014) shows that - under certain assumptions - the control function approach allows consistent estimates of the parameters in linear models or when the endogenous variable is continuous. In contrast, the discrete nature of the endogenous variable along with non-linear models, do not lead to a simple control function estimation. However, Wooldridge (2014) claims that using the first stage residual as control functions can be - hopefully - still useful to remove most of the endogeneity in the model.
The estimated model is composed by the following two equations:

$$y_1 = g_1(y_2, x, v_1), \tag{1}$$

$$y_2 = g_2(x^+, v_2), \tag{2}$$

with $x^+ = (x, z)$, where x denote the exogenous variables, while y_2 is the potentially endogenous variable and z is the instrumental variable which is correlated with the endogenous variable y_2 , but uncorrelated with the error term $v_2 : E(Z\varepsilon) = 0$. Considering equations (1) and (2) as a linear probability model (LPM), one could consistently estimates the coefficients using a two-stage least square technique. Alternatively, dealing with non-linear models we decide to adopt a control function approach. The control function approach consists in solving equation (2) for the error term and assuming the existence of a function $v_1 = h(v_2, u)$, such that u is independent of the regressors x and v_2. Then, the control function h can be plugged into equation (1):

$$y_1 = g_1(y_2, x, v_1) = g_1\big(y_2, x, h(v_2, u)\big) = \tilde{g}_1(y_2, x, v_2, u)\ .$$

Therefore, treating v_2 as if it were a vector of additional regressors, the error term in the model $\tilde{g}_1$ is u, which is independent of the regressors x and v_2. As a result, the model $\tilde{g}_1$ no longer has an endogeneity problem and so can be estimated in some standard way in place of the original model g_1.

The major limitation of this approach is that when the endogenous variable y_2 is discrete, then it is not possible that the error term v_2 is independent of x thus violating the assumption on u.[21] However, according to Wooldridge (2014) including the first stage residuals can be still useful to deal with the endogeneity in the model.

As pointed out by Wooldridge (2015), when the potentially endogenous variable is discrete, we need to assume the way in which the control functions enter the second stage equation. The simplest approach suggested by Wooldridge (2015) is just to add the fitted error term v_2 in the second stage equation. The first to suggest plugging in residuals from a discrete first-stage estimation into a second stage were Terza et al. (2008), who called this approach 'two-stage residual inclusion'.

Turning to our model, due to the binary nature of our endogenous variable (*university*), we estimate in the first stage the following logit model:

$$P(university \neq 0 \mid x^{+}) = \frac{exp(x^{+}\beta)}{1+exp(x^{+}\beta)}, \tag{3}$$

where $x^{+} = (x, weighted\_distance)$, and $x = (B, F, I,\ sectors, areas)$.

In equation (3) the vector of controls x^{+} has been augmented by the new variable *weighted distance* with respect to the vector x. Finally, we estimate the generalized residual $\hat{v}_2$ from the first stage as suggested by Wooldridge (2014, 2015) and we use it as a regressor in the second stage where we estimate the following multinomial logit equation:

$$P(y_1 = m \mid x') = \frac{exp(x'\beta_m)}{1+\sum_{h=1}^{M} x'\beta_h}, \tag{4}$$

where $x' = (x, y_2, \hat{v}_2)$. Because we include as a regressor the residuals from the first stage estimates, we compute correct standard errors by bootstrapping equation (6) as suggested in Terza et al. (2008) and Wooldridge (2014).

Before addressing the model described by equations (3) and (4) we consider the case in which the dependent variable y_1 is binary. The dependent variable y_1 takes value equal to 1 if the firm has a technological innovation between 2008 and 2020 and zero otherwise. This choice allows us to investigate if the university cooperation can foster technological innovation regardless of whether it is a pure technological innovation or joint to an organizational change in the firm. Moreover, it allows us to address the estimation problem as a limited probability model and to gain insights on the instrumental variable.

[21] A rigorous and detailed discussion of this approach is contained in Woodford (2014 and 2015).

5 Results on the link between Cooperation and Innovation

Accounting for firms' internal capabilities, i.e., considering the presence of absorptive capacity that enables firms to fully take advantage of the external cooperation for innovative activities, this paper aims at establishing whether there is an additional effect of firms' cooperation with universities on technological innovation. In other words, after cooperating with universities, do firms carry out technological innovations that would not have been otherwise performed?

This section summarizes our main findings; a more detailed discussion of the results is in the next two sub-sections. First, we compare no innovation activity (or only organizational) to technological innovation where we consider both 'pure' (only technological) and 'joint' (technological and organizational) innovation. Results show that cooperating with universities does not encourage additional technological innovation. This finding is partly in line with other studies which cannot find a clear-cut outcome on this aspect. What is evident in the literature is that the results depend on what one considers as the output of innovation. Some authors find an additional effect only on radical innovation (Monjon and Waelbroeck, 2003), others find an effect only on product and not on process innovation (Rouvinen, 2002) some others find the effect in the manufacturing sector but not in the service sector (Lööf and Broström, 2008)

Then, to go deeper in the analysis, we decide to investigate further the impact of cooperation on technological innovation by exploiting the dataset and splitting the effect on 'pure' and 'joint' (technological and organizational) innovation. We conduct this analysis constructing two different dependent variables and using two different sets of econometric models. In the first we consider a binary variable where we compare joint innovation to the rest, and in the second we consider a multivariate model where we consider the four different cases: no innovation,[22] only organizational, only technological, and joint. These two analyses both show that, once we isolate joint innovation, cooperation becomes significant.

In particular, the multivariate model points out that there is an opposite effect on 'pure' versus 'joint' technological innovation. Firms that cooperate with universities are more likely to adopt joint innovation, whereas firms that do not cooperate with universities are more likely to adopt pure technological innovations (the coefficient on pure technological innovation is negative). This result is in line with the fact that in the bivariate model, where there is no distinction between pure and joint innovations, the impact of cooperation is not significant. In other terms, the bivariate model that encompasses all types of technological innovation

[22] The category 'no innovation' includes firms that either introduced no innovation or that introduce types of innovation different from organizational and/or technological innovations.

('pure' and 'joint') in a single and broad category, cannot detect the different impact of university cooperation on the different types of technological innovations.

The fact that we find that cooperation between firms and universities only fosters those innovation activities which bind together the effort towards technological and organizational changes, is interesting since in the literature there is often a link between joint innovation and innovative performance. Ringberg et al. (2019) find for example that technological and organizational innovation together might involve a more intense change, making our results similar to those of Monjon and Waelbroeck (2003), who show an additional effect of cooperation on radical innovation. Joint innovations are relevant also because they are found to be more successful in transferring new ideas into market success (Cozzarin, 2017) and the complementarities between the two types of innovations (technological and organizational) might also increase the degree of complexity within the firm which can become an important source of competitive advantage (Rivkin, 2000).

This outcome is relevant especially for its policy implications. Policymakers should encourage the cooperation between firms and universities in Italy since the type of innovation it targets produces important changes in the economic system and turns out to be better than other types of innovation activities in promoting growth. In the next two sections we report our results and robustness checks in detail distinguishing between the two binary models and the multivariate one.

5.1 The binary model

We estimate the binary dependent variable, where 1 equals technological innovation (either pure or joint) and zero otherwise, using two different approaches. First, we estimate the binary outcomes using a linear probability model (LPM). Indeed, according to Angrist and Pischke (2009), the marginal effects of a dummy variable estimated by LPM are quite similar to those obtained by other non-linear techniques. However, addressing the endogeneity issue in linear models is much easier and can be solved by a two-stage least squares (2SLS) estimation. Moreover, in a linear model, the control function leads to the same estimated coefficients obtained by a 2SLS.

However, Lewbel et al., (2012) contrast the statement by Angrist and Pischke (2009). They claim it may occur that, using a LPM, the marginal effects may be quite different from non-linear models; moreover, in a LPM the error term cannot be independent of regressors. For this reason, we also estimate a non-linear model.

The results of the first stage are shown in Table 3. The coefficients estimated using a LPM are reported in column (a). The instrumental variable has a significant impact on the probability of cooperation and the sign is the expected one, since when the dummy variable switches from 0 to 1, the probability of cooperation between firms and university reduces of about 8 percentage points.

Table 3

First stage regressions. Average marginal effects.
(Dependent variable y2 =1 if firms cooperate with the universities and 0 otherwise)

	a) LPM			b) Logit		
	Coefficient		SE	Coefficient		SE
dummy weighted distance =1	-0.08111	***	*0.0221*	**-0.0790**	***	***0.0216***
R&D=1	0.05960	**	*0.0277*	0.0542	**	*0.0264*
research center=1	0.0984	***	*0.0255*	0.0834	***	*0.0225*
employees	0.0028		*0.0063*	-0.0010		*0.0044*
age	0.0591		*0.0528*	0.0389		*0.0418*
sales	0.0131		*0.0130*	-0.0022		*0.0133*
investments	0.0268	***	*0.0071*	0.0363	***	*0.0098*
blue-collar	-0.1675	***	*0.0632*	-0.2148	***	*0.0682*
district=1	0.0208		*0.0264*	0.0292		*0.0259*
Export						
export=1	-0.0009		*0.0288*	0.0018		*0.0347*
export=2	-0.0031		*0.0400*	-0.0010		*0.0406*
export=3	0.0592		*0.0423*	0.0423		*0.0418*
group						
group = 1	0.0210		*0.0220*	0.0205		*0.0223*
group = 2	0.0047		*0.0586*	-0.0042		*0.0428*
Obs.			1,125			

Source: authors' calculations
The coefficients are estimates of average marginal effect caused by the change in the independent variable. For factor variables discrete changes from the base case are reported. The definitions of variables are in Table A.1 in the appendix. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Standard error, reported in *italics*, are robust to heteroskedasticity and clustering on university (80 clusters). 11 Sector and 19 Regional dummies included.

Table 4

Summary results for the first-stage regression.
Tests of underidentification and weak identification

Variable	Sanderson-Windmeijer Chi-square	p-value	Kleibergen-Paap Wald rk F statistic	p-value
Cooperation	14.21	0.0002	13.52	0.0004
F statistic adjusted for 80 clusters in university				

Source: authors' calculations.

The Kleibergen-Paap F statistic for weak identification (Table 4) shows that we can reject the null hypothesis that the instrument is weak. Similar results are also reported in the column where a logit equation is estimated.

In accordance with the literature on the complementarity between internal and external sources (Cohen and Levinthal, 1990; Becker and Dietz, 2004), the variables used to account for firm's internal capability (namely *research center* and *R&D*) turn out to affect cooperation, confirming that firms are more likely to interact for research with external partners when they are more able to benefit from the cooperation. Among other variables, the probability of firm-university cooperation increases with the size of firm's investments and when the share of blue-collars reduces.

The second stage results are reported in Table 5. The OLS estimates in column (a) shows that the cooperation with universities has a positive effect on the innovation activity. However, when we control for the possible endogeneity the marginal effect becomes statistically insignificant. Column (b) reports the results of the 2SLS regressions, which shows that university cooperation does not affect technological change (the same results are replicated in column (c) using a control function approach). On the contrary, the probability of a technological innovation is positively correlated with the firm's capability measures (the existence of a research center in the firm or group and when the dummy signaling that firm spends in R&D activities).

Column (d) contains the estimates obtained using a control function and assuming a logistic function for both equation (5) and (6). The results are similar to the 2SLS. Standard errors are bootstrapped with 200 replications. As suggested in Wooldridge (2014. 2015) the first stage residuals are 'generalized residuals' that have zero mean conditional to x^{+}. Following Gourieroux et al. (1987) the generalized residuals in a logit model are defined as

$$\hat{v}_2 = y_2 - \frac{1}{1-e^{-x^{+}\hat{\beta}}} ,$$

where $\hat{\beta}$ are the estimated coefficients of equation (5). The first stage estimated generalized residuals are also used in the multinomial logit equation (5) whose results are discussed in the next section.

Table 5

Second stage regressions. Average marginal effects.
(Binary dependent variable y1 =1 if firms introduced a technological innovation and 0 otherwise)

	a) OLS			**b) LPM (2SLS)**			**c) Control function (linear)**			**d) Control function (logit)**		
	Coefficient		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**
Cooperation	**0.0644**	******	***0.0289***	**0.2180**		***0.3891***	**0.2180**		***0.3693***	**-0.0080**		***0.1495***
generalized residuals							-0.1552		*0.3652*	0.0774		*0.1638*
R&D	0.1911	***	*0.0311*	0.1820	***	*0.0378*	0.1820	***	*0.0394*	0.1908	***	*0.0332*
research center=1	0.1820	***	*0.0352*	0.1670	***	*0.0516*	0.1670	***	*0.0520*	0.1897	***	*0.0414*
Employees	0.0046		*0.0029*	0.0041		*0.0037*	0.0041		*0.0073*	0.0093		*0.0190*
Age	0.0515		*0.0515*	0.0419		*0.0508*	0.0419		*0.0576*	0.0629		*0.0554*
Sales	0.0039		*0.0126*	0.0013		*0.0127*	0.0013		*0.0146*	0.0030		*0.0143*
Investments	0.0071		*0.0085*	0.0030		*0.0133*	0.0030		*0.0130*	0.0097		*0.0100*
blue-collar	-0.0158		*0.0575*	0.0124		*0.0886*	0.0124		*0.0920*	-0.0297		*0.0700*
district=1	0.0230		*0.0352*	0.0207		*0.0374*	0.0207		*0.0392*	0.0217		*0.0349*
Export												
export=1	0.1360	***	*0.0368*	0.1361	***	*0.0371*	0.1361	***	*0.0375*	0.1253	***	*0.0314*
export=2	0.1329	***	*0.0415*	0.1328	***	*0.0415*	0.1328	***	*0.0421*	0.1248	***	*0.0442*
export=3	0.1109	**	*0.0515*	0.1014	**	*0.0560*	0.1014	**	*0.0567*	0.1088	**	*0.0425*
Group												
group = 1	-0.0108		*0.0333*	-0.0146		*0.0346*	-0.0068		*0.0312*	-0.0041		*0.0354*
group = 2	-0.0532		*0.0518*	-0.0551		*0.0511*	-0.0648		*0.0508*	-0.0618		*0.0555*
Obs							1,125					

Source: authors' calculations.
The coefficients are estimates of average marginal effect caused by the change in the independent variable. For factor variables discrete changes from the base case are reported. The definitions of variables are in Table A.3. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Standard errors are reported in *italics*: in columns a) and b) standard errors are robust to heteroskedasticity and clustering on university (80 clusters); in columns c) end d) standard error are bootstrapped with 200 replications. 11 Sector and 19 Regional dummies included.

In order to gain more insights about the interaction between cooperation and innovation, we adopt a different definition of the binary dependent variable y_1, which takes value equal to 1 when firms have introduced a joint innovation and zero otherwise. Once again, the second stage results are obtained assuming alternatively a LPM or logistic. The results are displayed in Table 6 (columns b-d). We find that the university cooperation is statistically significant in fostering firms' joint innovation activity. More precisely, the cooperation with a university increases the probability of joint innovation of about 87 percentage points when we use a two-stage estimation of LPM. However, the marginal effects reduce to about 34 percentage points when we use a control function where both the first and the second stage are modelled as logit equations.

Among other controls, we still find that the joint innovation activity is positively affected by the presence of a research center and R&D expenditure.

Table 6

Second stage regressions. Average marginal effects.
(Binary dependent variable y1 =1 if firms introduced a joint innovation and 0 otherwise)

	a) OLS			**b) LPM**			**c) Control function (linear)**			**d) Control function (logit)**		
	Coefficient		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**
Cooperation	**0.0512**		***0.0363***	**0.8729**	******	***0.4057***	**0.8729**	******	***0.3784***	**0.3435**	******	***0.1518***
generalized residuals							-0.8300	**	*0.3789*	-0.2993	*	*0.1811*
R&D=1	0.1086	***	*0.0307*	0.0601		*0.0456*	0.0601		*0.0382*	0.0826	**	*0.0345*
research center=1	0.1239	***	*0.0357*	0.0435		*0.0588*	0.0435		*0.0522*	0.0823	**	*0.0380*
Employees	0.0040		*0.0034*	0.0014		*0.0066*	0.0014		*0.0091*	0.0057		*0.0186*
Age	0.0038		*0.0552*	-0.0476		*0.0693*	-0.0476		*0.0609*	-0.0135		*0.0650*
sales	0.0249	**	*0.0113*	0.0109		*0.0151*	0.0109		*0.0143*	0.0139		*0.0139*
investments	0.0134	*	*0.0079*	-0.0083		*0.0125*	-0.0083		*0.0120*	0.0079		*0.0094*
blue-collar	-0.0313		*0.0527*	0.1195		*0.0944*	0.1195		*0.0876*	-0.0020		*0.0746*
district=1	0.0146		*0.0344*	0.0021		*0.0384*	0.0021		*0.0348*	0.0084		*0.0357*
Export												
export=1	0.0745	*	*0.0398*	0.0749		*0.0486*	0.0749	*	*0.0430*	0.0812	**	*0.0365*
export=2	0.0744	*	*0.0446*	0.0738		*0.0561*	0.0738		*0.0456*	0.0723		*0.0471*
export=3	0.0744		*0.0499*	0.0236		*0.0698*	0.0236		*0.0558*	0.0523		*0.0468*
Group												
group = 1	0.0105		*0.0308*	-0.0098		*0.0356*	-0.0098		*0.0275*	0.0049		*0.0347*
group = 2	-0.0195		*0.0528*	-0.0298		*0.0676*	-0.0298		*0.0471*	-0.0249		*0.0495*
Obs.						1,125						

Source: authors' calculations.
The coefficients are estimates of average marginal effect caused by the change in the independent variable. For factor variables discrete changes from the base case are reported. The definitions of variables are in Table A.3. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Standard errors are reported in *italics*: in columns a) and b) standard errors are robust to heteroskedasticity and clustering on university (80 clusters); in columns c) end d) standard error are bootstrapped with 200 replications. 11 Sector and 19 Regional dummies included.

5.2 The multivariate model

Tables 7 and 8 report the average marginal effects of the second stage of the multinomial logit, which describe how the control variables affect the probability of realization for each considered outcome. In the model the dependent variable has four mutually exclusive outcomes (*no innovation*, *organizational*, *technological*, *joint innovation*) and where the estimated residuals from the first stage (table 3) have been included among the regressors.[23] Bootstrapped standard errors are obtained by 200 replications. In table 7 the first stage is a LPM, while in table 8 we used a non-linear model. All the main results are similar.

The main finding reported in the tables is that the interaction with universities increases the probability of a joint innovation strategy by the firm but reduces the likelihood of a pure technological innovation with respect to non-collaborating firms. The results are interesting and shed some lights on the binary model outcome, where we have not distinguished between the firms' innovation strategies. Although the cooperation with universities does not increase the probability of technological innovation of firms, it differently targets the various types of technological innovation. In other terms universities stimulate firms to introduce new products or productive processes together with some organizational change. In contrast, it is less likely to observe firms that cooperate with universities and just adopt new products or productive processes that do not require any organizational or managerial change. Then, the multinomial model results are consistent with the findings displayed in table 8 where the binary dependent variable is equal to 1 in case of joint innovation and zero otherwise.

Finally, it is worth noticing that also in the multivariate model the measures of firms' capabilities (*research* and *R&D*) have statistically significant effects on the probability of both pure technological and joint innovations.

[23] The outcome variable is constructed so that each firm can not be in multiple categories. The estimated multinomial logit model satisfies the property of the independence of irrelevant alternatives (IIA), according to which the odds ratios should not be affected by the availability of alternative choices. Indeed, the introduction of an extra type of innovation does not change the firms' choice on previous innovation types.

Table 7

Second stage Multinomial Logit Regression. Average marginal effects.
(First stage: linear probability model)

	No innovation			Organizational			Technological			Joint		
	Coefficient		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**	**Coefficient**		**SE**
cooperation	**-0.1775**		***0.1766***	**-0.1601**	*****	***0.0862***	**-0.2033**	******	***0.0905***	**0.5409**	*******	***0.1729***
generalized residuals	-0.2128		*0.3794*	0.3907	*	*0.2287*	0.6846	***	*0.3363*	-0.8625	***	*0.3322*
R&D=1	-0.1658	***	*0.0393*	-0.0127		*0.0220*	0.1307	***	*0.0332*	0.0478		*0.0373*
research center=1	-0.1541	***	*0.0521*	-0.0099		*0.0321*	0.1345	***	*0.0453*	0.0295		*0.0468*
employees	-0.0003		*0.0295*	-0.0057		*0.0239*	0.0036		*0.0566*	0.0024		*0.0357*
Age	-0.0464		*0.0616*	-0.0041		*0.0353*	0.0895	*	*0.0520*	-0.0390		*0.0655*
Sales	-0.0157		*0.0169*	0.0176	*	*0.0104*	-0.0094		*0.0144*	0.0074		*0.0171*
investments	-0.0137		*0.0132*	0.0103		*0.0090*	0.0086		*0.0127*	-0.0053		*0.0127*
blue-collar	0.0657		*0.0967*	-0.0817		*0.0531*	-0.1068		*0.0898*	0.1228		*0.0910*
district=1	-0.02217		*0.0357*	0.0051		*0.0247*	0.0126		*0.0333*	0.0045		*0.0335*
export												
export=1	-0.1322	***	*0.0397*	0.0079		*0.0227*	0.0507		*0.0313*	0.0735	*	*0.0379*
export=2	-0.0945	*	*0.0508*	-0.0313		*0.0280*	0.0568		*0.0367*	0.0690		*0.0459*
export=3	-0.0877		*0.0542*	-0.0101		*0.0367*	0.0849	*	*0.0497*	0.0128		*0.0524*
group												
group = 1	0.0117		*0.0353*	-0.0020		*0.0194*	-0.0003		*0.0280*	-0.0094		*0.0299*
group = 2	0.0384		*0.0599*	0.0311		*0.0429*	-0.0240		*0.0441*	-0.0454		*0.0483*
Obs.						1,125						

Source: authors' calculations.

The coefficients are estimates of average marginal effect caused by the change in the independent variable. For factor variables discrete changes from the base case are reported. The definitions of variables are in Table A.3. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Bootstrapped Standard errors (200 replications) are reported in *italics*. Sector and Regional dummies included.

Table 8

Second stage Multinomial Logit Regression. Average marginal effects.
(First stage: logit model)

	No innovation			Organizational			Technological			Joint		
	Coefficient		SE	Coefficient		SE	Coefficient		SE	Coefficient		SE
cooperation	**0.0505**		***0.1538***	**-0.0862**		***0.0628***	**-0.2354**	*****	***0.0682***	**0.2710**	***	***0.1535***
generalized residuals	-0.2652		*0.2011*	0.1736		*0.1242*	0.4199	**	*0.1730*	-0.3283	*	*0.1818*
R&D=1	-0.1682	***	*0.0347*	-0.0264		*0.0185*	0.1141	***	*0.0287*	0.0806	**	*0.0323*
research center=1	-0.1591	***	*0.0381*	-0.0230		0.0223	0.1041	***	*0.0315*	0.0870	**	*0.0391*
employees	-0.0017		*0.0279*	-0.0072		*0.0199*	0.0046		*0.0434*	0.0043		*0.0292*
age	-0.0457		*0.0575*	-0.0184		*0.0370*	0.0694		*0.0478*	-0.0053		*0.0590*
sales	-0.0145		*0.0149*	0.0138		*0.0098*	-0.0157		*0.0131*	0.0164		*0.0149*
investments	-0.0141		*0.0112*	0.0036		*0.0071*	0.0035		*0.0111*	0.0070		*0.0124*
blue-collar	0.0707		*0.0749*	-0.0319		*0.0384*	-0.0830		*0.0797*	0.0442		*0.0864*
district=1	-0.0226		*0.0393*	0.0001		*0.0235*	0.0117		*0.0326*	0.0109		*0.0376*
export												
export=1	-0.1333	***	*0.0366*	0.0092		*0.0232*	0.0521		*0.0335*	0.0720	*	*0.0377*
export=2	-0.0964	**	*0.0448*	-0.0292		*0.0246*	0.0549		*0.0399*	0.0708		*0.0459*
export=3	-0.0915	*	*0.0471*	-0.0188		*0.0285*	0.0618		*0.0461*	0.0484		*0.0453*
group												
group = 1	0.0127		*0.0339*	-0.0106		*0.0200*	-0.0035		*0.0298*	0.0014		*0.0346*
group = 2	0.0361		*0.0573*	0.0267		*0.0406*	-0.0241		*0.0455*	-0.0387		*0.0486*
Obs							1,125					

Source: authors' calculations.

The coefficients are estimates of average marginal effect caused by the change in the independent variable. For factor variables discrete changes from the base case are reported. The definitions of variables are in Table A.3. ***, ** and * denote significance at the 1%, 5% and 10% level, respectively. Bootstrapped Standard errors (200 replications) are reported in *italics*. Sector and Regional dummies included.

6 Concluding remarks

We have provided robust evidence about the effects of the university cooperation on the technological innovation activity of Italian firms. The cooperation with universities does not encourage additional technological innovation, whereas it increases the likelihood of firms adopting a joint innovation strategy, which encompasses both technological and organizational improvements. The innovation management literature points out that the latter kind of innovation is the one that firms should preferably pursue to achieve market success. The results, based on data collected in the past decade, suggest that the cooperation with universities may be particularly useful for Italian firms to reduce the technological gap and increase productivity with respect to their main competitors. However, this empirical evidence is at odds with the low percentage of Italian firms collaborating with one or more universities, which is confirmed also by the most recent available data based on CIS 2018. This percentage is lower with respect to other advanced economies and imply that further efforts by the policymaker are needed to stimulate the firm-university cooperation.

Appendix

Table A.1. List of variables in the regressions

Variable name	Description	Nature
Dependent variables		
Innovation	**Innovative outcome**	Factor variable
innovation=0	No innovation	
innovation=1	Only managerial or organizational innovation	
innovation=2	New productive process and/ or new product	
innovation=3	Joint innovation (technological and non-technological)	
Instrument		Dummy
Dummy weighted distance=0	If distance (in Kms) between firms and universities, weighted for the Anvur index about the third mission below the median value	
Dummy weighted distance=1	If distance (in Kms) between firms and universities, weighted for the Anvur index about the third mission above the median value	
Independent variables		
University	**Type of collaboration with university**	Dummy
university=0	No collaboration or Firm hosting a Ph.d students / internships	
university=1	Consultancy and/or partnership in a research project	
Group	**Type of collaboration with university**	Factor variable
group=0	Firm does not belong to a group	
group=1	Firm belongs to an Italian group	
group=2	Firm belongs to a foreign group	
Age	Average age (100 years)	Continuous
employees	Average number of Employees (1,000 units)	Continuous
sales	Average sales (in natural logarithms)	Continuous
investments	Average investments (in natural logarithms)	Continuous
blue-collar	Average share of blue-collar workers	Continuous (between 0 and 1)
District	**Firm located in an industrial district**	Dummy
district=0	Firm is not located in an industrial district	
district=1	Firm is located in an industrial district	
Export	**Share of sales from export**	Factor variable
export=0	Non-exporting firm	
export=1	Export less than 1/3 of total sales	
export=2	Export between 1/3 and 2/3 of total sales	
export=3	Export more than 2/3 of total sales	
R&D	**Internal R&D spending o firm**	Dummy
R&D=0	Firm does not spend in internal R&D	
R&D=1	Positive firm's spending in R&D	
Research center		Dummy
research center=0	No research center in Italy or abroad	
research center=1	Firm has a research center in Italy or abroad	

Source: authors' calculations.
We do not report in the table 11 sectoral dummies and 18 regional dummies.

Table A2. Correlation matrix of the regressors.

	Coop	R&D	Research center	Employ-ment	Age	Invest-ments	Sales	Blue-collar	Export	District	Group
Coop	1										
R&D	0.2025	1									
Research center	0.2716	0.2745	1								
Employment	0.1251	0.1098	0.1132	1							
Age	0.1016	0.1156	0.1014	0.0609	1						
Investments	0.2896	0.2751	0.2418	0.3492	0.1617	1					
Sales	0.2765	0.2990	0.2622	0.3886	0.1900	0.7408	1				
Blue-collars	-0.1281	-0.1311	-0.1255	-0.1131	-0.0530	-0.1299	-0.3226	1			
Export	0.1733	0.2313	0.3092	0.0263	0.1258	0.1280	0.1575	0.0477	1		
District	0.0051	0.1193	0.0653	-0.0414	0.0400	-0.0814	-0.0148	0.0289	0.1609	1	
Group	0.2038	0.1952	0.3685	0.1321	0.0567	0.3879	0.4616	-0.2351	0.2108	-0.0561	1

Source: authors' calculations.

Table A3 Descriptive statistics according to innovative activity of firms.

Variables	No innovation		Pure Organizational innovation		Pure technological innovation		Joint Innovation		Full sample	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Age (years)	32.9	28	33.1	28	38.9	35	39.7	34	36.5	31
Number of Employees (units)	215	61	302	72	230	57	741	120	416	76
Sales (millions of euro)	58	12	172	19	209	11	246	26	163	17
Investments (millions of euro)	7.5	0.6	21.2	1.0	14.0	0.7	31.7	1.6	18.6	0.9
Share of blue-collar workers (percentage points)	63.7	73.3	57.3	63.5	66.6	70.2	61.2	67.4	62.8	70.0
					(percentage)					
University collaboration										
No University collaboration	74.5		67.1		59.3		53.9		62.7	
Loose collaboration (Internship)	13.5		19.3		14.7		15.5		15.0	
Collaboration (consultancy, partnership)	12.0		13.6		26.0		30.6		22.3	
Research center	21.5		15.9		49.5		57.8		39.4	
Internal R&D spending	29.1		31.8		60.3		66.1		48.4	
Share of exporting sales:										
Zero	47.3		50.0		19.1		16.3		31.1	
Less than 1/3	29.8		36.4		41.2		39.0		35.7	
Between 1/3 and 2/3	12.0		6.8		23.5		25.4		18.6	
More than 2/3	10.9		6.8		16.2		19.3		14.6	
Firms' groups										
No group	64.5		60.2		60.8		45.4		56.5	
Italian group	29.8		31.8		31.9		43.4		35.3	
Foreign group	5.7		8.0		7.3		11.2		8.2	
Belong to an Industrial District	20.6		20.5		31.4		32.0		26.7	
Geographical location:										
North-West	18.9		17.1		26.5		29.3		23.9	
North-East	11.6		20.4		15.2		21.5		16.5	
Centre	21.5		30.7		24.0		26.1		24.4	
South and Isle	48.0		31.8		34.3		23.2		35.2	
Economic sector:										
Food and Beverage	12.1		4.6		14.2		12.7		12.1	
Textile, clothing, leather, shoes	6.6		2.3		13.7		10.7		9.1	
Chemicals, rubber and plastics	4.7		5.7		9.8		11.2		8.1	
Energy and Extraction	5.7		8.0		8.3		6.1		6.5	
Engineering	23.6		13.6		34.3		36.6		29.5	
Other manufacturing	6.1		1.1		10.8		9.5		7.8	
Other not-manufacturing	3.8		6.8		3.9		0.2		2.7	
Wholesale and retail trade	18.2		22.7		2.5		5.4		11.0	
Hotels and restaurants	2.4		9.1		0		1.0		2.0	
Transport and communication	11.6		19.3		1.5		3.9		7.6	
Other business and household services	5.2		6.8		1.0		2.7		3.6	

Source: authors' calculations.

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