What are the trade-offs of academic entrepreneurship? An investigation on the Italian case.

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1 Introduction

The literature on technology transfer (TT) and the so-called third mission of the University is extremely wide and diversified. It encompasses both macroeconomic/country level analyses as well as microeconomic approaches or case studies, looking at the behaviour of single universities or researchers engaged in technology transfer activities[1].

From a macro perspective the available literature ranges from the effects of policy reforms aimed at promoting university-firms relations, such as the Bayh-Dole Act (see, for example, Grimaldi et al. 2011; Mowery et al. 2001; Shane 2004), to the performance of specific technology transfer tools, such as spin-offs or patenting (Bigliardi et al. 2013; Meseri and Maital 2001, only to cite some) or to the regional factors that lead to successful spin-offs and in some cases to important high technology clusters (Schweitzer et al. 2006). The stated aim of these studies is generally to understand whether a specific policy reform, or technology transfer mechanism, is effective in promoting a shift of academic research towards more productive uses and whether such a shift is desirable.

From a micro-perspective most of the literature has investigated the motivations that push individual researchers towards collaborations with firms (see, for example, Link et al. 2007; D'Este et al. 2005; Owen-Smith and Powell 2001) and the effects that such activities have on the academic productivity of the researcher (Breschi et al. 2008; Abramo et al. 2012; Lowe and Gonzalez-Brambila 2007; Lubango and Pouris 2009, and many more). In this latter case the final aim is to understand whether engaging in TT activities subtracts resources (in terms of time, effort, motivation and etc.) to the first two missions of the University.

In this study we wish to suggest a different perspective. What happens to the propensity to collaborate with firms, once the researcher creates her own venture? Do her collaborations decrease or do they grow? This question has been overlooked by the current literature, even though it carries important policy implications. As we shall see in section 2, existing analyses either investigate the determinants of spin-off creation or assess spin-offs' effectiveness by comparing their performances with that of other new technology based firms (NTBF). These two separate strands of literature mostly leave out the effects that spin-offs have on other forms of technology transfer, such as collaborations with other existing firms, which remain unexplored[2]. In this scenario, there is space to improve our understanding of the effects of spin-offs on technology transfer. Generally, spin-offs tend to be considered, *per se*, a form of technology transfer (see, among others, Müller 2010; Fontes 2005): by creating a company the researcher transfers her knowledge to a (new born) firm. Implicitly it is assumed that in the absence of such new venture that knowledge would have remained in the hand of the researcher and probably not exploited (or underexploited) for commercial purposes. However, we know that researchers have multiple channels to transfer technology to firms. What is not clear is the degree to which one channel substitutes for the others. For most countries, it is not empirically verified whether the transfer of knowledge to a new spin-off happens, for instance, to the detriment of the transmission of knowledge and technology to other existing firms. Nor is it clear the magnitude of such a phenomenon. In this sense, the different perspective that we propose might provide important suggestions for the debate on technology transfer and also some relevant policy implications. If spin-offs turned out, for instance, to substitute for collaborations with other firms, then promoting spin-offs might, *de facto*, divert

[1] For a review of contributions on the topic see Rothaemel et al. 2007.

[2] To our knowledge, one exception is the study of Van Looy et al. (2011), which looks at the trade offs between different forms of technology transfer. The analysis is however carried out at the university level and not in a quasi-experimental setting.

resources from existing firms to new ones, with potential effects on employment, competition, firms' growth, local development and so forth. Some of these potential effects might well be desirable, however at the moment they would be unintended and not explicitly envisaged in the policies supporting technology transfer. On the other hand, if spin-offs more than compensated (in terms, for instance, of publications and patenting capacity) for the (hypothetical) loss of transfer to existing companies, then there would be a further case to promote them. For all of these reasons, we believe that the above-mentioned effects need to be better understood and evaluated by means of empirical studies.

Our key suggestion is that the effectiveness of a technology transfer tool can be better assessed by taking into account the possible substitution for other channels of knowledge transfer. By comparing the behaviour of single researchers, before and after the establishment of their own firm, with the behaviour of a control group, we study the degree of substitutability between different TT mechanisms, namely spin-offs and research collaborations with firms. Specifically, we assess whether those academics that founded a firm significantly change their attitude to perform research collaborations with other firms after establishing their own company, compared to a group of similar scholars. In addition we also monitor the overall patenting and publication rate before and after the creation of the academic enterprise. We do so by analysing an original dataset that includes all academic entrepreneurs in Italy during the period 2000-2007, as well as a control group of similar non-entrepreneurial researchers.

This article substantially adds to the existing literature in several ways. First, it is the only study, to our knowledge, that considers the universe of academic entrepreneurs and their relations with other firms in Italy. It is also one of the few analyses that creates a control group of a large number of academic entrepreneurs in order to investigate the evolution of their research behaviour. Moreover, it offers an analytical framework that allows simultaneous consideration of *formal* and *informal* TT mechanisms (Link et al., 2007) and thus it begins building a bridge between microeconomic and macroeconomic analyses of technology transfer. In particular, we consider at the same time the collaborations with firms (measured by co-patenting and co-publications), as well as academic spin-offs (ASOs). Finally, we assess the effectiveness of spin-offs in a different way than previously done by most of the literature. We do not compare spin-off firm performance with that of other new technology firms (implying a counterfactual situation where the academic entrepreneur could, and would, have founded another firm in the absence of the spin-off). Rather we assume that, in the absence of the spin-off, she would have transferred technology in other ways and in particular by collaborating with existing companies. In this perspective, as already remarked, our results can stimulate further researches, with implications for other fields of study such as policies to promote local development, entrepreneurship and competition.

The paper is structured as follows. Section 2 briefly reviews the relevant economic literature, focusing first on the determinants of spin-off creation that are particularly relevant to the choice of explanatory variables in our empirical model. Secondly, we recall the previous studies addressing the effectiveness of spin-offs. This review sets the conditions to present our research hypotheses. Section 3 describes the dataset, introduces the model and the methodology. Section 4 presents and discusses our findings. Section 5 concludes.

2 Literature Review

A comparison of academic entrepreneurs with controls that could have founded a new venture (but did not) requires, first of all, to discuss the factors influencing the probability of starting a new company.

According to the existing literature, the likelihood of setting up an academic spin-off depends upon the individual characteristics of the founder (Stephan and Levin 1996; Shane 2001) as well as of the surrounding environment (university or local context) where she operates (Fini et al. 2009).

At the *individual level* a number of personal characteristics have shown to be important for spin-off creation. Among these are subjective personal features such as: entrepreneurial self-efficacy and confidence (Can I be a good entrepreneur?) (Fini et al. 2009), opportunity recognition skills (Baron and Ensley 2006, Clarysse et al. 2011), ability to search for different ways of pursuing their research agenda (Meyer 2003), and the need for independence (Cassar 2007). For a review of the literature on personal motivations see Hayter (2011) and Rubini and Miglietta (2014). Given their intrinsic nature, these factors can be analysed only by means of direct interviews and questionnaires, carried out on relatively small-sized samples.

Other personal factors are objective and therefore can be measured in studies with large samples. First of all, the human capital of the founder and the academic reputation positively influence the transition to entrepreneurship (Varga 2006; Stuart and Ding 2006). A typical variable used in the literature to proxy human capital is the years of education (Aldridge and Audretsch 2011), and also the number of publications, both of which are a general measure of scientific quality that correlates with the probability of patenting and therefore with the probability of founding a company (Renault 2006; Landry et al. 2002; Landry et al. 2006).

Moreover, business experience and industrial know-how can be very useful in the spin-off process by supporting the identification of opportunities. Prior industrial collaborations amongst the academic founders help them understand the potential commercial viability of their research (D'Este et al. 2005; Landry et al. 2007; Shane 2000; Clarysse et al. 2011).

An additional important personal asset of the academic entrepreneur is the number of years of research activity. More experienced researchers may have more to "sell" in terms of accumulated skills, increased access to complementary expertise, additional equipment and additional resources, and may be less motivated by traditional university incentives such as tenure or academic awards (perhaps because they have already been achieved), and more attracted by greater financial incentives (Louis et al. 1989; Etzkowitz 1983). In particular, Zucker et al. (1994) find that the so-called "star scientists", i.e. those with outstanding academic records measured by the number of citations, are more likely to establish a firm.

Finally, the literature has considered the role of the university and the *local context* in stimulating academic entrepreneurship (Clarysse et al. 2011; Rizzo, 2015; Di Gregorio and Shane 2003; Rasmussen et al. 2014). For example, there are contributions analysing the impact of technology transfer offices (TTOs) as well as other forms of support to academic entrepreneurship. The results are not unequivocal. In some cases the activities of TTOs and university support in general appear to increase patenting activity and commercialisation of research (Siegel and Wright 2015; Rasmussen and Borch 2010), while in others the investment and efforts made by universities to support spin-offs are not seen to be additional incentives (Fini et al. 2009). Meoli and Vismara (2014) even find out that academic spin-offs are more frequent (in comparison with alternative technology transfer mechanisms) when the support from the university is scarce or inadequate. Finally, there are studies concentrating on the role of social capital for spin-off formation. In general, there seems to be a direct relationship between the two elements (Landry et al. 2002), because social capital is important in the processes of fund raising, acquiring and hiring surrogate entrepreneurs, accessing information and knowledge (Vohora et al. 2004). In this perspective, a faculty member's transition to entrepreneurship is easier in universities where the phenomenon of academic entrepreneurship is well known, because it is easier to follow a path (Etzkowitz 1998; Shane and Stuart 2002; Stuart and Ding 2006).

When coming to assess the effectiveness and desirability of spin-offs, the current empirical literature has focused on their role in sustaining employment and entrepreneurship in knowledge-based sectors (Colombo et al. 2010; Iacobucci and Micozzi, 2015), facilitating the diffusion of research from academia to firms (Lawton Smith 2007; Harrison and Leitch 2010; Wright and Mustar 2010) and evaluating their financial and economic performances (Furlan and Grandinetti 2014). Most of these studies compare the performance of spin-offs with that of other NTBFs (Colombo and Piva, 2008; Ortín-Ángel and Vendrell-Herrero 2014, only to cite some). Many of them highlight a general weakness of the spin-off, due, in part, to entrepreneurial inexperience of the academic founder (who tends to focus on technology instead of markets) or to conflicting objectives (Harrison and Leitch 2010; Iacobucci et al. 2011).

Several studies furthermore looked at the general relationship between entrepreneurial universities and academic productivity, coming to contrasting results (for a review on this issue see Larsen 2011). Coming closer to our perspective, few scholars have tried to assess the desirability of spin-offs by specifically studying the consequences of academic entrepreneurship on academic performances. Lowe and Gonzales-Brambila (2007), for example, find a generally positive impact of spin-off formation on scientific productivity. One possible explanation is that academic entrepreneurs actively protect their position within the university, even after the ASO establishment (Van Looy et al. 2011). Buenstorf (2009) identifies instead a negative effect on the long term academic productivity of scientists (measured by publications and citations records). This effect could be simply due, as the author suggests, to a shrink in the time available for pure academic activity or to a decreasing interest in academic research of more aged researchers (who are more prone to establish a spin-off).

Nevertheless, both works are conducted on specific cases or small samples that could have affected the final results. To our knowledge, the only available study analysing large scale data (the whole set of national academic spin-offs) is that presented in Abramo et al. (2012). They analyse the Italian case and they conclude that the research performance of academic entrepreneurs, over the entire period considered, is higher than the average of all other researchers in the same field. Such performance remains essentially equal before and after the establishment of a spin-off. This would suggest a null effect of spin-offs on publishing performance. However, the authors do not take into account that the propensity to found a spin-off is higher for more productive researchers (Zucker et al. 1994; Van Looy et al. 2011). By comparing academic entrepreneurs with *all* other researchers, they possibly overestimate the impact on scientific productivity. Only by matching academic entrepreneurs with the colleagues that had the same likelihood to establish a firm (especially in terms of prior productivity) can we better identify the net effect. We therefore expect such effect to be negative[3].

We thus formulate our first hypothesis as follows:

Hypothesis 1*: Creating a spin-off decreases the number of publications of researchers.*

While there are a few examples of studies analysing the relationship between patenting and knowledge transfer (Crespi et al. 2011), to the best of our knowledge there is no specific literature on the impact of spin-offs on the patenting propensity of academic researchers. Existing studies consider patenting performance as one of the determinants of spin-off

[3] This negative effect can also been explained by the fact that publications are typically not a priority output for firms. Furthermore, academics engaged in commercialization activities tend to delay the publication of research results, withhold data and limit the access to research materials (see Larsen 2011 for further details).

generation, but the reverse relationship is not tested. We know that academic entrepreneurs, compared to their colleagues, tend to have higher prior patenting performances (Landry et al. 2006; Stuart and Ding 2006; Krabel and Mueller 2009). Thus we can safely assume them to be particularly capable and aware of the advantages and disadvantages of patenting already before the establishment of the company. The effect on patenting, under this assumption, is most probably null. We cannot however exclude a priori a possible positive effect due to an increase in the human and financial resources available for R&D, triggered by the entrepreneurial activity.

> ***Hypothesis 2****: creating a spin-off has either a null or positive effect on the overall patenting performance of researchers.*

The existing empirical analyses are equivocal about the desirability of spin-offs as mechanisms of technology transfer.

As mentioned above, the literature casts doubts on their effectiveness by comparing their performance with that of NTBFs. This approach implicitly creates a counterfactual scenario where scientists could and would have founded another company, had they not engaged in their own venture. Alternatively, some of the literature considers ASOs as a transfer of technology "by definition". In this case it is implicitly assumed that the knowledge and technology in the hand of the researcher would not have been transferred at all, in the absence of the new academic venture.

Our approach is different. We suggest that a more relevant choice (and, hence, study design) is between transferring technology to an existing firm (through research collaborations) and transferring it to a new self-owned company. With this view, spin-offs could affect the number of publications with other firms (co-publications) and the number of patents developed with other firms (co-patents).

We therefore feel that an improved study design, with a quasi "experimental/control" setting will lead to clearer answers on the question of how spin-offs either substitute for or complement other forms of technology transfer. This is the main difference with our study design.

The theory would suggest that there are both incentives and disincentives for an academic entrepreneur to start or maintain collaborations with other firms once the new company is established. Intuitively, once the researcher becomes an entrepreneur she has less motivations to collaborate with other firms (we can call this "competition effect"). First of all because other firms can be competitors and therefore the academic entrepreneur might be reluctant to share knowledge and technology (Colombo and Piva 2012). Secondly, she might be particularly concentrated in launching the company and less in establishing linkages with other firms, especially in the early stages. However, there might be several reasons for academic entrepreneurs to engage in collaborating activities (we can call this "collaboration effect"). Collaborations on R&D and patenting among knowledge intensive firms are rather common and they have proven to be particularly important for NTBFs to develop innovative activities (Storey and Tether 1998). They can help share the risks of investment in R&D, stimulate vertical or horizontal commercial agreements, favour the acquisition of new knowledge and the development of common product platforms, and so forth (see, among others, Powell et al. 1996; Belderbos et al. 2015; Un and Asakawa 2014). In addition, commercial alliances with non-academic firms can be of particular importance in the early phases of the university spin-off because they give access to commercial assets and competencies that are often missing (Colombo and Piva 2012).

The final attitude of the academic entrepreneur to collaborate depends on which of the two effects prevails. Some literature suggests that research collaborations are more difficult for basic research than for applied research. This is because the potential commercial development of basic research is less clear and under such uncertainty firms prefer to share less (Sinha and Cusumano 1991; Narula 2004; Colombo and Piva 2012). If we take publications as a proxy of basic research and patents as a proxy of applied research, then we expect to see a substitution effect between technology transfer realised by means of establishing a spin-off and by means of co-publications. In other words we hypothesize the "competition" effect to be greater than the "collaboration" effect in the case of co-publications.

Hypothesis 3*: Creating a spin-off will lead co-publications with the spin-off to substitute for co-publications with other firms.*

In the case of co-patenting, on the other hand, the benefits from collaboration can exceed the potential damages of cooperating with competitors. It seems in fact easier to formalize a collaboration when the potential commercial use of the result is made clear at the initial stages of the process. In this case we can expect the "collaboration effect" to exceed the "competition effect" and determine an additional impact of spin-offs on co-patents with firms. For this reason we formulate our last hypothesis as follows:

Hypothesis 4*: Creating a spin-off will not lead co-patents with the spin-off to substitute for co-patents with other firms.*

We take hypotheses 3 and 4 as being the most innovative part of this study.

3 Data, model, and methodology

3.1 Building the database

In this study we compare a group of academics who actively participated in an entrepreneurial venture with a group of "similar" academics who did not. Therefore the data collection is comprised of two databases. One includes academic entrepreneurs (Group A, *the "treatment sample"*), and the other is the sample of academics who did not established a start-up (Group B, the "untreated" or "*control sample*").

Group A (academic entrepreneurs)

Our empirical analysis is based on a unique hand-collected database built by the authors[4], which comprises all ASOs created in Italy between 2000 and 2007 (most of them being founded in the last two years). We have then selected only the 115 spin-offs still active in 2011. In effect, we are narrowing our "treatment group" to *successful* academic entrepreneurs. For each of these spin-offs, information about ownership and governance have been collected by examining their balance sheets. These, provided by the Italian Chamber of Commerce, notably enabled us to distinguish among various types of investors: individuals, public research institutions, venture capitalists and similar, industrial firms, and other investors. We focus on individuals. The initial set included 838 founders of the 115 selected Italian spin-offs. We have then excluded those associates who entered the spin-off after its foundation. In other words, our investigation is particularly focused on those academics that

[4] The initial database is publicly accessible at: www.spin-offitalia.it. It contains data for the period 2000-2012 on the general characteristics of Italian spin-offs (name, year of foundation, university of foundation, sector of activity, location, etc.) and on their economic performance (sales, profits, employees, etc.). It also provides information on TTOs.

a) chose to establish a new firm and not just to participate in an existing one and b) were involved in the business for the whole study period. Subsequently, we have cross-checked every founder with the list of academics employed in Italian universities in the study years, using data available from the Italian Ministry of University and Research (MIUR). This has allowed us to select only those with tenured academic positions in the year of foundation. In the Italian university system, these faculty members include researchers, associate professors and full professors. Finally, we have included in our database only those spin-off associates who had an academic position at the time of spin-off foundation as well as 5 years before and 5 years after. This led to a new dataset of 221 spin-off academic associates that represents therefore the universe of researchers and professors involved in an academic spin-off for the entire study period. It excludes post-doc and temporary research assistants.

For each of the 221 selected academics we have collected the following information: academic position at the time of founding of the spin-off, academic position 5 years before and 5 years after, scientific field (*Settore Scientifico Disciplinare*, SSD), university of affiliation, number of academic entrepreneurs per 100 academics for each university in the sample, presence of an ILO (Industrial Liaison Office) in the university of affiliation, number and characteristics of *publications* 5 years before and 5 years after the spin-off's founding using the SCOPUS database, whether the academic is a star scientist (measured both by the coordination of at least one national research project and the number of citations received until the establishment of the spin-off), gender. By analysing every publication for each academic, we have identified the total number of publications for the two periods, the total number of citations for the two periods, the number of publications with co-authors whose affiliation was a firm, the number of firms involved in each publication, the number of publications where the only firm mentioned in the authors' affiliations was the spin-off and the number of publications where the spin-off appeared in the authors' affiliations along with other firms.

In addition, we have collected information on the number and characteristics of *patents* on which the selected academics appeared as inventors during the 5 years before and 5 years after the spin-off establishment using the European Patent Office database. In particular, we have identified the total number of patents, the number of patents with firms among the applicants and the number of patents with the spin-off among the applicants.

Group B (controls)

To identify a group of comparable non-entrepreneurial academics (*group B*) we have used the MIUR database, with a first selection of all academics operating in the same SSD of *group A* in the year of the spin-off founding, regardless of the academic position or the university. This has led to the construction of a pool of 150,907 academics, with information on the academic position for the considered time span and the scientific field. We have then further selected only those operating in the same year, the same SSD, the same university and the same academic position as the 221 academic entrepreneurs (group A). This has led to a subgroup of 604 non-entrepreneurial academicians, who constitute our control group. For all of these 604 academics we have analysed both publications and patents, collecting the same information as for group A.

In order to avoid mistakes due to cases of homonymy, the affiliation and the research content of each single publication and patent has been checked, both for the treated and the control group. A total of 30,274 publications and 527 patents have been analysed in detail.

3.2 The Model and the methodology

The model assesses the effect of creating a spin-off on a number of dependent variables. We identify what the causal inference literature calls the "*average treatment effect on the treated* (ATT)". To do so, we use propensity score matching (PSM) to compare scholars that founded a spin-off with academics that had in the same years a similar probability of starting a spin-off, but chose not to do so.

The advantages of PSM as a matching estimator have been extensively noted, making it one of the most commonly used tools in non-experimental evaluation studies (Bryson et al. 2002, Martini et al. 2006, Dehejia and Wahba 1999). In particular, propensity score allows to perform statistical matching in the presence of a high number of relevant covariates by reducing them to a unique balancing score. On the other hand, PSM, and matching in general, rests upon the hypothesis that the selection into treatment – in our case establishing a spin-off - is based on observable variables. In the robustness checks in the appendix we discuss the consequences of relaxing such hypothesis in our case.

In this study the propensity score is the probability of doing a spin-off conditional on a certain set of covariates:

$$p(X)\equiv Pr(Spinoff=1|X)\equiv E(Spinoff|X)$$

□ □⍰ ≡ Pr⍰ where *Spin-off* is a dummy variable corresponding to 1 if the academic has founded the spin-off and 0 otherwise and *X* is the set of covariates. The propensity score *p(X)* can be used to obtain an unbiased estimate of the average treatment effect on the treated (ATT) provided that Conditional Independence Assumption (CIA) and Common support hypotheses hold (Caliendo and Kopeinig 2008, Imbens 2004):

$$\tau_{ATT}=E[Y(1)|Spinoff=1,p(X)]-E[Y(0)|Spinoff=1,p(X)]$$

where □ □ 0⍰⍰ $E[Y(0)|Spinoff=1,p(X)]$ is the usual counterfactual term.

We assess the effects of the spin-off creation on different outcomes of interest, as stated in the hypotheses in section two. We consider co-patents and co-publications as proxies of the research collaborations between scholars and firms, as well as total publications and total patents as a measure of the general scientific productivity of the researcher. While estimating the effects of spin-offs on co-patents and co-publications we keep separate those that are done with other firms, from those that are done with only the spin-off company. While estimating the effects of spin-offs on the general productivity in terms of total patents and publications we distinguish pure academic products (no firm is involved), products where only the spin-off is involved (but not other firms) and products that involve other firms. We do so because, even though the spin-off is often considered *per se* a transfer of technology to a new firm, this might be to the detriment of collaborations with other firms and we want to be able to assess this possible effect.

Table 1 summarises our main dependent variables and the expected impacts.

Table 1 Outcome variables: description and expected effects

Outcome		Description	Expected effect of spin-off
	PUB_5_POST_TOT$_i$	total number of publications in the five years following the spin-off (same time span for the corresponding matched controls)	negative
Hypothesis 1	*of which* PUB_5_POST_SC$_i$	number of "purely academic" publications without any firm among the authors in the five years following the spin-off (same time span for the corresponding matched controls)	
	PAT_5_POST_TOT$_i$	total number of patents in the five years following the spin-off (same time span for the corresponding matched controls)	positive or null
Hypothesis 2	*of which* PAT_5_POST_SC$_i$	number of patents without any firm among the applicants in the five years following the spin-off (same time span for the corresponding matched controls)	
Hypothesis 3	**COPUB_5_POST_TOT$_i$**	sum of the number of publications with firms (equal to	negative or null

		COPUB_5_POST$_i$ for the corresponding matched controls)	i.e. *Substitutive* *
	of which COPUB_5_POST$_i$	number of publications with at least one firm among the authors' affiliations - *excluding* the spin-off - in the five years following the spin-off (same time span for the corresponding matched controls)	
	COPUB_5_POST_SOi	number of publications with *only* the spin-off among the authors' affiliations in the five years following the spin-off (equal to COPUB_5_POST$_i$ for the corresponding matched controls)	
Hypothesis 4	**COPAT_5_POST_TOT$_i$**	sum of the number of patents with firms (equal to COPAT_5_POST$_i$ for the corresponding matched controls)	positive i.e. *Additive**
	of which COPAT_5_POST$_i$	number of patents with at least one firm among the applicants – *excluding* the spin-off - in the five years following the spin-off (same time span for the corresponding matched controls)	
	COPAT_5_POST_SOi	number of patents with the spin-off among the applicants in the five years following the spin-off (equal to COPAT_5_POST$_i$ for the corresponding matched controls)	

* Precisely: if the effect is null it indicates that in the absence of the spin-off the same number of co-publications would have been realized with other firms (*substitution* effect). If the effect is negative it means that in the absence of the spin-off the researcher would have published with other firms and at a higher rate (*diminishing* effect). If the effect is positive it means that academic entrepreneurship generates *additional* co-patents, that would not have been realized otherwise.
Source: authors' elaboration

We choose the set of covariates *X* to calculate the propensity score, consistent with the CIA requirement that only the variables that affect both the decision to setup a spin-off and the outcomes of interest should be included when estimating the propensity score (Caliendo and Koepinig 2008). Our set of covariates includes: ACA_POSi - academic position at the foundation of the spin-off (same year for the corresponding matched controls); SSDi - scientific field; UNIi - university of affiliation; YEARi – year of foundation of the spin-off (same year for the corresponding matched controls); SO100ACADi - number of academic entrepreneurs every 100 academics in the university of affiliation and in the year of spin-off foundation (same year for the corresponding matched controls), PAT_5_PREi – number of patents in the five years preceding the spin-off; COPUB_5_PREi - number of publications with at least one firm among the authors' affiliation in the five years preceding the spin-off; COPAT_5_PREi - number of patents with firms among the applicants in the five years preceding the spin-off; CIT_PREi: number of citations received by the academic until the spin-off establishment. Table 2 shows the summary statistics for the main covariates used to compute the propensity score and for the outcomes of interest for the whole sample and for the two groups.

Table 2 – Summary statistics for the main covariates and for the outcomes of interest: full sample, academic entrepreneurs and controls

	Mean values			T-test on means		
	Full sample	Academic entrepreneurs (treated)	Academic colleagues (controls)	Difference in means	T-statistic	p-value
Main covariates						
PAT_5_PRE	0.250	0.448	0.177	0.271	3.41***	0.001
PUB_5_PRE	16.472	19.303	15.435	3.868	2.34**	0.020
COPAT_5_PRE	0.147	0.222	0.119	0.103	1.65	0.101
SO100ACAD	0.758	0.993	0.672	0.321	3.87***	0.000
CIT_PRE	664.383	638.887	673.712	-34.825	-0.33	0.745
Outcome variables						
PUB_5_POST_TOT	20.224	23.222	19.127	4.094	2.04**	0.042
PUB_5_POST_SC	17.690	19.136	17.161	1.975	1.11	0.266
PAT_5_POST_TOT	0.389	0.756	0.255	0.501	4.26***	0.000
PAT_5_POST_SC	0.112	0.136	0.103	0.033	0.89	0.373
COPUB_5_POST_TOT	2.535	4.086	1.967	2.119	4.15***	0.000
COPUB_5_POST	2.167	2.715	1.967	0.748	1.81*	0.070
COPUB_5_POST_SO	1.807	1.371	1.967	-0.596	-1.67*	0.096

COPAT_5_POST_TOT	0.278	0.620	0.152	0.468	4.30***	0.000
COPAT_5_POST	0.205	0.348	0.152	0.196	3.04***	0.003
COPAT_5_POST_SO	0.184	0.271	0.152	0.119	1.60	0.111
CIT_POST	1271.916	1180.131	1305.500	-125.369	-0.71	0.480
Obs	825	221	604			

Source: authors' elaboration

The mean values for all of the dependent variables are higher for the treated group than for the control group, except for the citations received after the foundation of the ASO (CIT_POST). This might suggest that academic entrepreneurs generally have better performances in terms of productivity with respect to their colleagues. However, we are not considering that the control group might include both individuals that are likely to start a self-owned enterprise and individuals that are not. To correct for potential bias arising from poor comparability of the two groups we use a propensity score matching method.

Different matching possibilities on the p-score are available from the literature (Caliendo and Koepinig 2008). In particular, we choose to use radius matching with a caliper equal to 0.08. With radius matching, the treated observations are matched with all the controls with a propensity score lying within a specified range of values (caliper). Compared to the other matching methods, this technique is thought to confer a good balance between the quality of the matching and the number of treated observations included in the estimation (Becker and Ichino 2002).

4 Empirical results

Table 3 shows the results of the logit regression estimating the probability of establishing a spin-off (the propensity score). The test statistics suggest an overall significance of the variables included in the model and a good explanatory power compared to most of the logit regressions in the existing literature on the topic.

Table 3 The propensity to be an academic entrepreneur: logit regression

Y_i	Coeff.	Std. Err.
ACA_POS_i		
Full professor	(base)	
Associate Professor	0.3570	0.3552
Non-Confirmed Associate Professor	1.6213***	0.5571
Confirmed Researcher	0.3675	0.3972
Non-Confirmed Researcher	0.9803	0.6901
$PAT\_5\_PRE_i$	1.3980***	0.2698
$PUB\_5\_PRE_i$	0.0143**	0.0070
$COPAT\_5\_PRE_i$	-1.2757***	0.3269
$SO100ACAD_i$	-1.4453**	0.6531
CIT_PRE_i	0.0002*	0.0001
Constant	-968.8037**	453.9105
University dummies	Yes	
Year	Yes	
Disciplinary sector (SSD) dummies	Yes	
Obs	802[a]	
LR X^2 (111)	226.17	
$P > X^2$	0.000	
Log likelihood	-342.7866	
Pseudo R^2	0.2481	

Significance levels: *** 1%, **5%, *10%.

[a]: The total number of observations is reduced to 802 because the estimation perfectly predicts 16 success cases (spin-off=1) and 7 failure cases (spin-off=0).

Source: authors' elaboration

The results confirm the significance of several factors highlighted by the literature on the determinants of spin-off creation. In particular, the previous scientific productivity, measured by the number of both publications and patents in the five years preceding the spin-off has a positive effect on the propensity to spin-off. We also find that the university effect is significant. On the other hand, we do not find confirmation that academic seniority *per se* has a positive impact on spin-off propensity. Instead, non-confirmed associate professors seem to have the greater propensity towards academic entrepreneurship. This could endorse the thesis of some of the literature that spin-offs are perceived as means to acquire scientific prestige by researchers that are building their reputation and carriers (Rizzo 2015; Franzoni and Lissoni 2006). Existing collaborations with the private sector, measured by the pre-treatment level of co-patents, have a negative impact. This might be a first indication that spin-offs and co-patents are perceived as substitutes for one another. The percentage of academic entrepreneurs per 100 academics (in each university) also appears with a negative sign. This variable captures the diffusion of academic entrepreneurship at the local (university) level. The result is apparently counterintuitive. However, the estimation is produced "ceteris paribus" the university effect. In other words, we can assume that the university effect captures the reputation and attitude of university towards spin-off creation, while the presence of many other entrepreneurs mirrors a discouraging effect on potential ventures. This discouraging effect could appear if the perceived competition is high and the resources for technical and financial assistance from the academic institution are limited. Finally, in line with what suggested by the literature, being a "star scientist" increases the chances of creating a spin-off. In particular, the total number of citations, as a proxy of the research impact, is significant, as shown in table 3.

Table 4 shows our main results after matching. Columns 1 and 2 report the means of the outcomes for each group, while column 3 displays the ATT. All academic entrepreneurs are included in the estimation of the ATT as well as all the observations for the control group.

Table 4 Average effects (ATT) of spin-offs on the main outcome variables: radius matching (caliper 0.08)

Variable	(1) Mean for the treated	(2) Mean for the controls	(3) ATT
PUB_5_POST_TOT	23.795	37.255	-13.460*** (3.901)
PUB_5_POST_SC	19.449	33.852	-14.403*** (3.571)
PAT_5_POST_TOT	0.785	0.757	0.029 (0.157)
PAT_5_POST_SC	0.146	0.352	-0.206*** (0.065)
COPUB_5_POST_TOT	4.346	3.402	0.944 (0.897)
COPUB_5_POST	2.873	3.402	-0.529 (0.838)
COPUB_5_POST_SO	1.473	3.402	-1.929** (0.808)
COPAT_5_POST_TOT	0.639	0.404	0.235* (0.135)
COPAT_5_POST	0.346	0.404	-0.058 (0.096)
COPAT_5_POST_SO	0.293	0.404	-0.111 (0.105)
CIT_POST	1216.995	3145.399	-1928.404*** (360.636)
Treated on support			205
Treated off support			0
Untreated on support			597
Untreated off support			0

Significance levels: *** 1%, **5%, *10%. Standard errors in brackets
Source: authors' elaboration

Before commenting on the results we highlight that there are no particularly large correlations among the outcomes of interest, especially between publications and patenting (see tab. A4 in the appendix). There is a high correlation between patents and co-patents. However, this does not seem to interfere with final results, given that the variables show different behaviours and significance levels.

The results confirm our main hypotheses about the effect of spin-offs on the publishing and patenting behaviour of Italian researchers. We observe a significant effect on the overall publishing performance (*hypothesis 1 accepted*). Such effect is negative, meaning that academic entrepreneurs publish less than their colleagues after founding their own venture. This result is mainly driven by a decrease in "pure academic" publications.

As regards patenting, the effect of spin-offs on the whole patenting performance is not significant, suggesting that after becoming an entrepreneur the academic does not decrease the patenting activity with respect to her similar colleagues (*hypothesis 2 accepted*).

Coming to publications with other firms, the number for academic entrepreneurs (copub_5_post) is not statistically different from that of similar colleagues. At the same time the publications that the academic entrepreneurs realise only with their own spin-off are much less than what the colleagues do with other firms (copub_5_post_so is negative and significant). The effect that deserves more attention, however, is the total number of co-publications with firms (copub_5_post_tot): it indicates that, even when taking into account also the publications done *only* with the spinoff company, the total number of co-publications with firms is not different from what similar non-entrepreneurial colleagues do. In other words: had the researcher not founded the spin-off, she would have published with another company what is instead published with her own. This result confirms the existence of a substitution effect between spin-offs and co-publications with firms (*hypothesis 3 accepted*).

For the co-patenting activities, some other interesting results emerge, consistent with our hypothesis. Academic entrepreneurs patent more with firms than similar colleagues, as seen by the positive and significant effect on copat_5_post_tot. They do not substitute co-patenting with other firms for co-patenting with the spin-off: in this case the effect of the spin-off is additional (*hypothesis 4 accepted*).

At the same time, there is a significant and negative effect of patents filed as a "scientist", meaning patents that were invented by the researcher and either owned by herself or, more often, by other institutions (i.e. universities, hospitals, research centres and so forth). As said, the overall effect on patents is null. Academic entrepreneurs patent *just as much as* their similar colleagues after the establishment of the spin-off. However, what they most probably do in the post-period is patenting with their own company what was before patented and owned by themselves or by other non-commercial institutions. This is, of course, in line with the expected results of academic entrepreneurship. Yet, it has been recently noted that there is a lack of empirical evidence on the *actual* degree of commercialisation of university-owned and university-invented patents, as well as their market value, compared to that of other commercial institutions (Giuri et al. 2011; Crespi et al. 2010; Sapsalis et al. 2006).

As a final additional notice, it must be highlighted the highly significant and negative effect on the number of citations for academic entrepreneurs in the post-period. If we agree on citations as a proxy of the impact of the research, such impact diminishes alongside with the overall productivity of researchers. This is in part due to a correlation between total number of publications and number of citations (see tab. A4 in appendix). Nevertheless, the decrease in citations is stronger: in the post period, while academic entrepreneurs publish 36% less than controls, their citations diminish by 61%.

In the Appendix we show the results of the robustness checks and sensitivity analyses we have performed. First of all, the distribution of the estimated p-score across the two groups is displayed (Figure A1). For such a distribution, we found that the radius matching with a relatively small caliper (0.08) is a good compromise between the need to keep as many observations as possible and the need to ensure comparability between academic entrepreneurs and controls. Table A1 reports the balancing test statistics to verify the performance of different matching estimators, table A2 shows the ATTs for different calipers and for the kernel matching, table A3 reports Rosenbaum bounds (Rosenbaum 2002) to test the sensitivity of the results to unobservable variables. All the tests confirm that our results are reasonably robust. However, the results for co-patents are less strong to the presence of unobservables than others.

5 Conclusions

The general aim of making the results of academic research suitable for commercial uses has been pursued with vigour by many industrialised and industrialising countries in the last decades. Promoting the transfer of knowledge and technology from universities to firms has been a priority in the agenda of many governments. Italy makes no exception. Since the late 1990s the country has placed great emphasis on the third mission of the university and on the transfer of technology to the industry (Barbieri 2010). Toward these ends, the creation of firms by academic researchers has emerged as a preferred instrument, alongside the traditional research collaborations between universities and firms. ASOs have significantly grown in number and have been promoted by more and more universities all over the country (Di Tommaso and Ramaciotti 2010). However, such a growth does not seem to have been rooted enough in the empirical evidence of the trade-offs of academic entrepreneurship.

While the desirability of spin-offs as a form of new technological entrepreneurship has received sufficient attention by the international literature, less has been said on spin-offs as technology transfer tools compared to the other forms of TT used by academic researchers. In particular, it seems to us that the Italian academic and political debate has not fully analysed and understood the trade-offs of academic entrepreneurship.

This paper has targeted a specific issue that has been little explored by the literature: the existence of substitution effects between different forms of technology transfer (particularly research collaborations and spin-offs). It has done so by analysing a unique dataset covering the universe of Italian spin-offs as well as a large control group of similar academics.

When comparing the results of patenting and publication performances we can make some final remarks on the effectiveness of spin-offs as technology transfer tools in Italy. Our results suggest that spin-offs do not increase the transfer of technology to firms by means of co-publications: they instead crowd-out publications with other firms. In other words results suggest that, in the absence of the spin-off, such knowledge would have been transferred anyway to an existing firm. This effect appears to be partly compensated by an increase in technology transfer by means of co-patents, although our results do not allow distinguishing if such increase comes from patents with the spin-off or with other firms. Further research is needed to clarify this point. At the same time our results show a general deterioration in the academic activity of researchers that become entrepreneurs.

In this overall framework, our analysis on the Italian case makes us wonder if a widespread spin-off promotion is worth the effort. Such promotion often requires investment of public money to create firms that, in many cases, are less performing than other NTBFs (among others, Iacobucci et al. 2010; Zahra et al. 2007) and it comes at the expenses of the overall productivity and quality of the research of the scholars involved.

This paper is not an attempt to argue against spin-offs. It is an attempt to add evidence on the *net* impacts of academic entrepreneurship, with the aim to improve policies for technology transfer and to limit their downsides.

We have offered a first contribution in this direction. Further research on the topic is possible and desirable. It could clarify, for instance, whether the crowding-out regards in particular local firms, which are substituted, for example, by international ones. Moreover, qualitative investigations could add evidence on the role of individual unobserved factors affecting both the decision to become an entrepreneur and the patenting productivity of researchers. It could also shed light on the presence of heterogeneous effects, particularly across different disciplinary fields or different individuals.

If this is the case, our results would be reinforced in suggesting that spin-offs should not be viewed as a *panacea* for the lack of commercialisation of university researches, nor would they be desirable everywhere and in any case. Rather, they can be a powerful tool to promote precise technological domains (Iacobucci and Micozzi 2015) and particular emerging industrial clusters, provided that they are supported by a clear view of the long-term objectives of the specific local context of reference.

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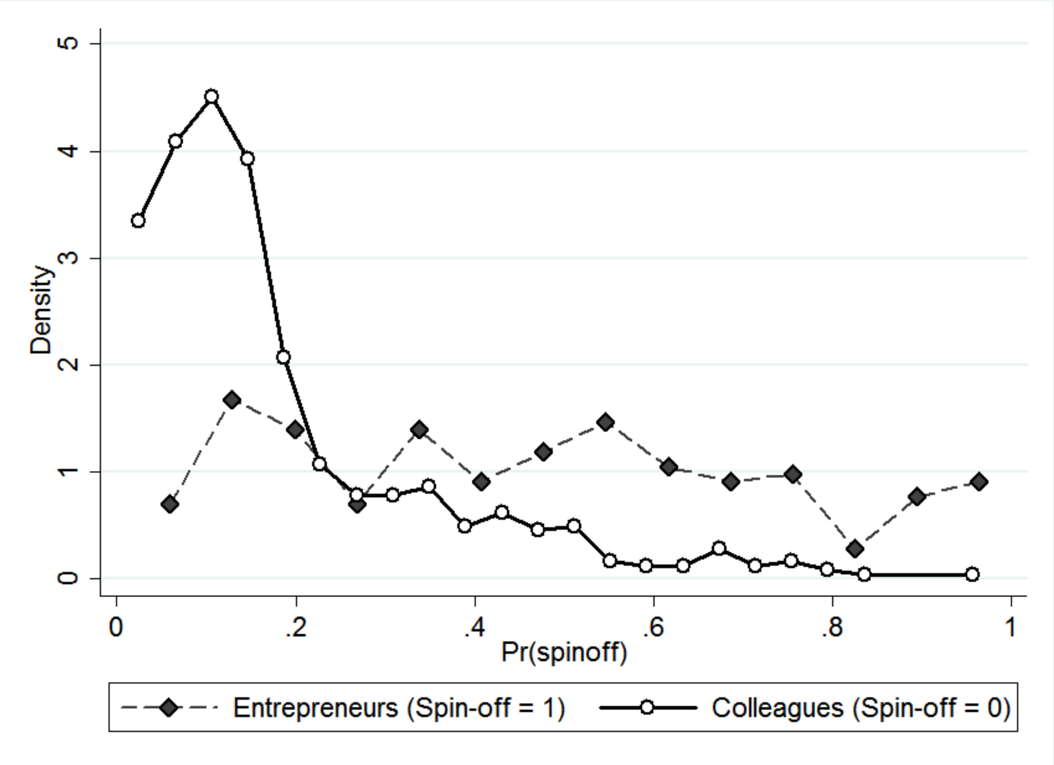
Appendix A

Figure A1 – Distribution of the propensity score for academic entrepreneurs (treated) and their colleagues (controls)



Source: authors' elaboration

Note: The two distributions run almost across the whole range of values of the p-score. That is, there is no evidence that a failure of the common support hypothesis may hold (Becker and Ichino 2002, Lechner 2002). In order to avoid bad estimates of the treatment effect, we should carefully match treated units with controls that are not too different (in the value of the score). For such purposes, we use radius matching with caliper equal to 0.05. Compared to the other matching methods, we consider this technique to confer a good balance between the quality of the matching and the number of treated observations included in the estimation.

Table A1 Robustness checks: balancing test statistics for different matching procedures

Matching method	Sample	Pseudo R^2	$p>X^2$	Mean Bias	Median Bias	Rubin's B	Rubin's R	% variance
	Unmatched	0.248	0.000	8.1	5.6	125.0	2.07	77
Radius	Matched	0.085	1.000	5.8	3.3	67.3	1.07	53
NN	Matched	0.190	0.242	9.1	6.8	87.5	4.43	71
Kernel	Matched	0.053	1.000	4.4	2.8	53.6	0.92	48

Source: authors' elaboration

Note: Radius matching: the values of the Pseudo R^2 and the p-value of the likelihood-ratio test for the radius matching suggest that the covariates no longer explain the difference in the mean values of the outcomes after the matching procedure. The bias is also reduced by 30 to 40%, as it is shown in the mean and median values, together with the percentage of variables with extreme variance in the F-distribution. The only statistic falling outside the range usually identifying a good matching is the Rubin's B – although it is reduced to about a half than in the unmatched sample -, while the Rubin's R drops from 2.07 to a completely acceptable value of 1.07 (Rubin 2001). Compared to the radius results the NN performs much worse leading to a bad matching. Results for the kernel are comparable to the radius matching. However, we must recall that (1) the kernel matching associates each observation for the treated with a function of all controls, thereby including also controls that have substantially different characteristics from our academic entrepreneurs (2) the kernel matching estimates the effect of the treatment only inside the common support (Lechner 2002).

Table A2 - ATTs with different matching estimators

Variable	Radius matching, caliper 0.05	Radius matching: caliper 0.1	Kernel matching

					(on common support)	
	ATT	Std. Err.	ATT	Std. Err.	ATT	Std. Err
PUB_5_POST_TOT	-9.646***	(3.430)	-12.653***	(3.743)	-7.832**	(3.286)
PUB_5_POST_SC	-10.887***	(3.120)	-13.568***	(3.422)	-9.177***	(2.983)
PAT_5_POST_TOT	0.144	(0.152)	0.083	(0.154)	0.149	(0.150)
PAT_5_POST_SC	-0.170***	(0.058)	-0.182***	(0.062)	-0.163***	(0.056)
COPUB_5_POST_TOT	1.241	(0.806)	0.915	(0.864)	1.345*	(0.776)
COPUB_5_POST	-0.266	(0.735)	-0.558	(0.803)	-0.160	(0.701)
COPUB_5_POST_SO	-1.733**	(0.698)	-1.958**	(0.773)	-1.593**	(0.664)
COPAT_5_POST_TOT	0.314**	(0.134)	0.265**	(0.133)	0.312**	(0.132)
COPAT_5_POST	0.017	(0.090)	-0.027	(0.094)	0.013	(0.088)
COPAT_5_POST_SO	-0.050	(0.100)	-0.081	(0.103)	-0.054	(0.098)
CIT_POST	-1569.045***	(316.061)	-1822.645***	(345.680)	-1416.410***	(302.231)
Treated on support	195		205		194	
Treated off support	10		0		11	
Untreated on Support	597		597		597	
Untreated off Support	0		0		0	

Significance levels: *** 1%, **5%, *10%.

Source: authors' elaboration

Note: The table presents the results obtained by using kernel matching and radius matching at different calipers (0.05 and 0.1). The results from the chosen matching method (radius with caliper 0.08) remain robust across different matching methods, the only exception made for COPUB_5_POST_SO in kernel matching. However, we have already described the limits related to the use of the kernel matching.

Table A3 - Rosenbaum bounds for significant ATTs

Variables	Gamma[a]	p-critical[b]	HL[+c]	HL[-d]	CI[+e]	CI[-f]
PUB_5_POST_TOT	1.40	0.041	-10.647	-3.245	-14.336	0.465
	1.45	0.063	-11.054	-2.879	-14.756	0.888
PUB_5_POST_SC	1.70	0.036	-12.435	-2.940	-15.731	0.250
	1.75	0.051	-12.709	-2.699	-16.061	0.551
PAT_5_POST_SC	3.55	0.045	-0.528	-0.070	-0.567	0.106
	3.60	0.052	-0.528	-0.070	-0.567	0.118
COPUB_5_POST_SO	3.20	0.047	-3.693	-0.595	-4.208	0.130
	3.25	0.055	-3.725	-0.571	-4.228	0.194
COPAT_5_POST_TOT	1.00	0.980	-0.106	-0.106	-0.144	-0.023
CIT_POST	2.25	0.040	-1422.95	-282.489	-1861	47.040
	2.30	0.056	-1443.14	-263.225	-1894.33	70.221

N=195 matched pairs; [a] Log odds of differential assignment due to unobservables; [b] Significance level bounds: lower bound for PUB_5_POST_TOT, PUB_5_POST_SC, PAT_5_POST_SC, COPUB_5_POST_TOT, CIT_POST; upper bound for COPAT_5_POST_TOT; [c] Hodges-Lehmann point estimate: upper bound; [d] Hodges-Lehmann point estimate: lower bound; [e] 95% confidence interval: upper bound; [f] 95% confidence interval: lower bound;

Source: authors' elaboration

Note: Outcomes related to total publishing, publishing as a scientist, patenting as a scientist, co-publishing with the sole spin-off and citations are rather robust to the presence of hidden bias. The level of gamma at which our conclusions become insignificant at 5% significance level are: between 1.40 and 1.45 (PUB_5_POST_TOT); between 1.70 and 1.75 (PUB_5_POST_SC); between 3.55 and 3.60 (PAT_5_POST_SC); between 3.20 and 3.25 (COPUB_5_POST_SO); between 2.25 and 2.30 (CIT_POST). On the other hand, the levels of gamma at which unobservables are assumed to impact on the results for COPAT_5_POST_TOT lowers to 1, which signals high sensitivity of such outcomes to hidden bias. These are *worst scenario* estimates, in that Rosenbaum's approach supposes that the unobservables have an almost deterministic effect both on the propensity to found a spin-off and on the outcomes of interest (Di Prete and Gangl 2004).

Table A4 – Correlation among outcome variables

	pub_5_post	pub_5_post_sc	pat_5_post	pat_5_post_sc	copub_5_post_tot	copub_5_post	copub_5_post_so	copat_5_post_tot	copat_5_post	copat_5_post_so	cit_post
pub_5_post	1.000										
pub_5_post_sc	0.975***	1.000									
pat_5_post	0.171***	0.125***	1.000								
pat_5_post_sc	0.090***	0.090***	0.534***	1.000							
copub_5_post_tot	0.466***	0.259***	0.245***	0.033	1.000						
copub_5_post	0.445***	0.244***	0.215***	0.029	0.963***	1.000					
copub_5_post_so	0.417***	0.225***	0.055	0.019	0.920***	0.914***	1.000				
copat_5_post_tot	0.157***	0.103***	0.915***	0.147***	0.271***	0.237***	0.056	1.000			
copat_5_post	0.096***	0.067	0.803***	0.190***	0.154***	0.147***	0.044	0.848***	1.000		
copat_5_post_so	0.148***	0.104***	0.827***	0.167***	0.230***	0.204***	0.074**	0.888***	0.713***	1.000	
cit_post	0.746***	0.712***	0.126***	0.030	0.410***	0.416***	0.389***	0.132***	0.061*	0.137***	1.000

Source: authors' elaboration