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**Determinants of growth in research spin-offs: a
resource-based perspective**

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There are strong expectations towards research spin-offs, but insufficient empirical evidence still exists on the determinants of growth of such companies. The aim of this paper is to contribute to the debate on growth -or non-growth- of research spin-offs through a focus on Italy. A resource-based perspective is adopted for identifying the crucial determinants of competitive advantage of these companies, and an OLS regression analysis is performed to assess the impact of initial resources on growth in revenues and employees. Our analysis highlights unexpected results about the involvement of industrial partners, venture capitalists, size of IPRs' portfolio at founding and previous experience of the promoting partners.

Key-words: *Academic entrepreneurship - research spin-offs - Technology transfer - Knowledge valorisation - Resource-based view.*

Il existe de fortes attentes en ce qui concerne les entreprises spin-off de la recherche, mais il existe encore peu d'évidence empirique sur les déterminants de la croissance de ces entreprises. L'objectif de cet article est de contribuer au débat sur la croissance - ou la non-croissance- des entreprises spin-off de la recherche en mettant l'accent sur l'Italie. Une perspective basée sur les ressources est adoptée pour identifier les déterminants cruciaux de l'avantage concurrentiel de ces entreprises, et une analyse de régression OLS est effectuée pour évaluer l'impact des ressources initiales sur la croissance des revenus et des employés. Notre analyse met en évidence des résultats inattendus concernant la participation de partenaires industriels, de capital-risqueurs, la taille du portefeuille de DPI à la fondation et l'expérience antérieure des partenaires de promotion.

Mots-clés : *Entrepreneuriat académique - Entreprises spin-off de la recherche - Transfert de technologie - Valorisation des connaissances - Théorie du management par les ressources.*

Las empresas "Spin off" de la investigación han generado grandes expectativas pero aún no hay suficiente evidencia empírica sobre los determinantes del crecimiento de esas empresas. El objetivo del artículo es contribuir al debate sobre el crecimiento o no crecimiento de las empresas "Spin off" de la investigación destacando el caso de Italia. Adoptamos un enfoque basado en los

recursos para identificar los determinantes fundamentales de la ventaja competitiva de dichas empresas y efectuamos un análisis de regression OLS para valorar el impacto de los recursos iniciales sobre los ingresos y el personal. Nuestro análisis pone en evidencia resultados inesperados referentes a la participación de socios industriales, de capitalistas de riesgo, al tamaño de la cartera de DPI, a la fundación y anterior experiencia de los socios de promoción.

Palabras-clave: *Iniciativa empresarial académica - Empresas “Spin off” de la investigación - Transferencia de tecnología - Valorización de conocimientos - Teoría del management por los recursos.*

Introduction

Research Spin-Offs (RSOs)¹ are a kind of start-up companies that has been attracting increasing scholarly attention in recent years (Miranda et al., 2018; Mathisen, Rasmussen, 2019). RSOs are supposed to bring scientific and technological knowledge from public research to the market, and to exert a positive impact on economic development at the regional and national levels (De Cleyn, Festel, 2016).

Despite the recent advancements in understanding RSOs' structure and main characteristics (Mustar *et al.*, 2008; Freitas *et al.*, 2013; Fryges, Wright, 2014; De Cleyn, Festel, 2016), and the numerous attempts to explain the influence of RSOs' structure on their early growth (Mustar, 1997; Heirman, Clarysse 2004; Chapman *et al.*, 2011; Visintin, Pittino, 2014; Hayter, 2016; Ferri *et al.*, 2019) their development paths are still relatively unexplored. As shown by Greiner (1972; 1998), specific phases of evolution (growth) and revolution (crisis) characterise organisations' development, each connected with specific organizational practices and managerial problems. Only a few studies have systematically attempted to explain the critical factors determining the diversity in performance of RSOs (Vohora *et al.*, 2004; Lockett, Wright, 2005; Lawton Smith, Ho, 2006; Bock et al., 2018; Mathisen, Rasmussen, 2019). RSOs have mostly been investigated as one of the outcomes of universities' knowledge transfer activities (Chiesa, Piccaluga, 2000; Lockett, Wright, 2005; Algieri et al., 2013), and the prevailing use of qualitative research methods and cross sectional-data (Visintin, Pittino, 2016) has posed serious constraints to the interpretation of causal relationships between growth determinants and outcome variables, limiting the generalizability of the results.

These arguments lead us to argue that more quantitative research is needed on the growth determinants of RSOs and, more specifically, on the role that different bundles of resources at the time of their founding play in their development process (Barney 1991;

¹ In this article we adopt the definition of RSOs provided by Benghozi and Salvador (2014: 51): “firms established by current or former university/research centre members (e.g., professors, researchers, technical and administrative staff and Ph.D. candidates) for the purpose of exploiting research results, regardless of whether the firm holds a university share or patent”.

Chandler, Hanks, 1994; Barney *et al.*, 2001). While relevant studies have explored the initial configurations of resources on which RSOs are based (Heirman, Clarysse, 2004), only a few analyses investigate the link between RSOs' endowment and performance (see, e.g. Czarnitzki *et al.*, 2014). Considering that RSOs hold high technical knowledge background (Clarysse *et al.*, 2011), they are often able to be active on the market since founding. Consequently, it is feasible and innovative to investigate RSOs resources endowment at founding to identify the determinants of growth. To this purpose, and building on previous research (Boeker, 1989; Geroski *et al.*, 2010) we argue that RSOs founding conditions may have a long-term effect on firms' growth. To this aim, five research hypotheses are tested, concerning three groups of resources (founding conditions) which are commonly considered important for technology-based entrepreneurship and, specifically, for RSOs: (i) technology, (ii) finance and (iii) human resources (management and entrepreneurship).

Italy represents an interesting empirical setting for the analysis of RSOs' development (Piccaluga, 1992). First, the number of RSOs founded each year has been constantly growing since the early 1990s (Netval, 2018). Second, Italian universities have issued specific set of rules to manage the RSO phenomenon (Salvador, 2009; Cesaroni, Piccaluga, 2016). Third, several policy initiatives to support RSOs' development have been launched in Italy at the regional and national levels, like the creation of several Technology Transfer Offices. Nonetheless, the results of our analysis can be generalized beyond the Italian case, as European RSOs share most of the same characteristics and problems (Mustar *et al.*, 2008; Clarysse *et al.*, 2011; Rasmussen, Wright, 2015).

After setting the theoretical framework, we formulate our research hypotheses, we introduce the control variables included in the model and then we describe the research method used. Finally, we report and discuss the results of our analysis.

Theoretical framework and research hypotheses

Several researchers expressed doubts about the real extent of rapid growth potentials of *all or most* RSOs, since the indiscriminate attribution of this characteristic was not corroborated by robust evidence (Vohora *et al.*, 2004; Wright *et al.*, 2007). Several studies show, in fact, that the vast majority of new technology-based firms remain small or very small (Mustar, 1997; Chiesa, Piccaluga 2000; Harrison, Leitch, 2007). Regarding growth processes of new ventures, they are argued to be a complex and multidimensional phenomenon (Wright *et al.*, 2007; Rasmussen, 2011) and no single theory can fully explain them in general, and in the case of RSOs in particular. However, the growth patterns of young ventures are not completely random and unpredictable; rather, they are systematically related to the characteristics of the firms and to their environment (Smallbone *et al.* 1995; Delmar *et al.*, 2003). Previous research argues that founding conditions may have a long-term effect on firm growth and performance (Boeker, 1989) and the organization's history and stages of development may influence and determine its future success (Greiner, 1972, 1998).

The Resource-Based View of the firm (RBV) suggests that the identification and acquisition of a set of initial resources shapes firms' ability to conceive and implement value creation strategies (Barney, 1991; Chandler, Hanks, 1994; Barney *et al.*, 2001), playing a key role for survival and success (Roberts 1991; Carter *et al.* 1994). In this perspective, the entrepreneurial challenge consists in the identification and acquisition of starting resources (Penrose, 1959), including: a) *technology* (Utterback *et al.*, 1988); b) *finance* (Roberts, 1991; Manigart *et al.* 2002); c) *human resources* (Roberts, 1991; Barney, 1991; Shane, Stuart, 2002). As suggested by Barney (1991), to identify the determinants of growth of RSOs, we build on these three categories of resources (Barney, 1991) and formulate five research hypotheses as follows.

RBV: technology

Intellectual Property Rights (IPRs) are fundamental building blocks of a RSO aspiring to become a successful company (Walter *et al.*, 2016). The availability of IPRs at founding reveals the degree of technological endowment of research-based start-ups while, from a market perspective, IP protection allows new companies to

successfully exploit new product development efforts. Empirical research has included patents among the factors influencing the likelihood of RSOs formation (Shane, 2004) and success (Shane, Stuart, 2002) and has demonstrated that RSOs' growth seems to be related to their patent portfolios (Niosi, 2006; Stephan, 2014; Ferri et al., 2019). Regarding IPRs granted to RSOs, Shane and Stuart (2002) used patents' stock at the time of founding and Grandi and Grimaldi (2003) adopted the number of patents and licences assigned to academic entrepreneurs as indicators of the 'technological excellence' of the new venture. Based on these considerations, we hypothesise that:

Hypothesis 1-(H1): *RSOs holding IPRs (patents and/or licences and/or trademarks) at founding will grow more than RSOs without IPRs in their portfolio.*

RBV: finance

Concerning financial capital resources, this paper investigates the effects of the involvement of Venture Capital investors (VCs) in RSOs. Since insufficient financial resources are often cited as a primary reason for the failure of new ventures (Florida, Kenney, 1988), VCs may play a key role in financing RSOs, especially in the biotechnology and pharmaceutical sectors (Zucker *et al.* 1998; Wright *et al.*, 2006) and, in this context, may play an important role steering professionalization of academic entrepreneurs (Hellman, Pury, 2000). Empirical research has largely investigated this aspect. In particular, Davila *et al.* (2003) found a positive association between the presence of VC and high growth, attributable to venture capitalists' ability to select firms with high growth potential or to post-investments benefits that accrue to VC-backed RSOs.

VCs are pivotal market actors that can provide not only financial resources, but also market credibility to RSOs (Fernandez-Alles et al., 2015). Findings by Gubitta et al. (2016) suggested an indirect impact on the growth of the RSOs' sales through the mediating effect of VC financing and Bock et al. (2018) highlighted that VC-backed RSOs showed higher employment and revenue growth compared to non-VC-backed RSOs. Mustar (1997) highlighted instead that in France the creation of RSOs relied more on public financing than on the availability of VC. Building upon this

contrasting evidence, it seems worth to test the impact of the formal involvement of VCs among the company shareholders as a proxy of the ability of RSOs to attract equity capital during the first years of operation. We therefore hypothesise that:

Hypothesis 2-(H2): *RSOs having raised VC during their first years of operation will grow more compared to RSOs starting without the formal involvement of VC.*

RBV: human resources (management and entrepreneurship)

The RBV theory suggests that a critical founding asset for the development of innovative RSOs is access to human resources holding knowledge and talent (Powers, McDougall, 2005). Empirical research has largely demonstrated that the personal characteristics of the entrepreneurial team, such as education, experience and maturity, represent pre-entry capabilities playing an important role as predictors of new ventures' success (Eisenhardt, Schoonhoven, 1990; Roberts, 1991; Cooper *et al.*, 1994).

Based on literature on nascent entrepreneurship, relevant firm-specific human resources in newly established RSOs are identifiable within different forms of managerial and entrepreneurial experience of the founding teams (Stuart, Abetti, 1990; Cooper *et al.* 1994; Shane, Stuart, 2002). Heirman and Clarysse (2004) found that the entrepreneurial culture of the promoting partners is positively related to growth processes: more experienced founding teams grow faster. Commercial experience leads to high growth, but it is often lacking in the mostly technical founding teams of RSOs (Shane, 2004; Wright *et al.*, 2007; Mustar *et al.*, 2008; Salvador, Benghozi, 2015). Based on these considerations, we test the following hypothesis:

Hypothesis 3-(H3): *RSOs started by founding teams with previous experience not only in R&D but also in business and managerial domains will grow more compared to RSOs started by teams with only R&D experience.*

According to the literature, the quality of the entrepreneurs' education represents one of the factors predicting entry into nascent entrepreneurship, since it will positively affect the likelihood of holding financial capital (it represents an important criterion for VCs' evaluation) and technological capital (IPRs) at founding (Davidsson,

Honig 2003; Ganotakis 2012). However, and although human capital resources are central to the RBV argument, research still shows contrasting results with respect to individual qualities of the founders on medium-long term growth (Roure, Keeley, 1990). The relevance of these arguments in the context of RSOs lead us to test the following hypothesis:

Hypothesis 4-(H4): The share of doctoral graduates over total employment will positively impact RSOs growth.

The formal involvement of an industrial shareholder among the promoting partners of the RSO or at least its entry during the first years of operation may be expected to provide the firm with a significant inward flow of knowledge and professional skills in different functional domains and it is likely to impact positively on firms' development paths. In this respect, Roure and Keeley (1990) argued that in order to grow, a firm should accept and manage growth processes, including the willingness to add new shareholders. Agarwal et al. (2004) observed that interaction with industry through the promoting partners is more effective than knowledge acquisition through hiring experienced employees. Nonetheless, Benghozi and Salvador (2014) analysis of RSOs with and without traditional industrial partnerships revealed the absence of significant differences in development and performance between the two groups of companies. Because of this contrasting evidence and in order to shed further light on this strategic aspect, the fifth hypothesis will test if:

Hypothesis 5-(H5): RSOs in which one or more industrial partners took an equity stake since the first year of operation will grow more compared to RSOs without such shareholders.

Control variables

We controlled for a set of context-related variables, which are suitable to affect medium-long term growth of RSOs.

Industry

In the literature, there is some evidence about dissimilarity of new ventures' growth paths depending on the sectors in which they are involved (Delmar *et al.*, 2003). About the Italian context, the preferred areas of technology transfer processes from academia to

industry through spinning-off of new ventures have progressively changed, by switching from ICT, mechanics, electronics, energy and environment in the early '70s to the growing interest nowadays for biotechnologies, pharmaceutical, nanotechnologies, and Internet-based activities (Netval, 2018).

Competitive forces

The industrial organization literature argues that a firm's performance is dependent also on how the firm positions itself in the industry. In this perspective, the firm is a bundle of strategic activities aimed at positioning the venture on the market (Porter, 1980). Sandberg and Hofer (1987) found that venture strategies as well as competitive forces in the industry have an impact on the success of new ventures. Therefore, we control for four competitive forces: (i) threat of new entrants, (ii) threat of substitutes and bargaining power of (iii) buyers and (iv) suppliers. Controlling for direct competitors can be difficult and even misleading in the context of RSOs because of the extreme novelty of their products/services for which industry boundaries are very vague.

Local context

The support provided by the local context to RSOs may be relevant (Shane, 2004). Gilbert *et al.* (2006) argued that geographic location influences new ventures' growth. With regard to Italy, the historical territorial unbalances between the North and the South - the "Italian innovative divide" (Iammarino *et al.*, 2009) - make the local context a relevant factor for RSOs creation. Building upon this evidence, we included in the model two control variables indicating the supportive level of the local context to academic entrepreneurship and the macro-region of localisation of RSOs (North, Center, South). We also included growth in R&D investments and age of the firm as control variables, in order to assess how the relationship between critical resources (founding conditions) and growth of RSOs varies in time (Coad *et al.*, 2016).

Methodology

For the identification of the population of Italian RSOs² we collected information from a diversified range of sources: *i*) contacts with universities and other public research institutes; *ii*) contacts with business incubators and science and technology parks; *iii*) monitoring of regional and national business plan competitions; *iv*) emerographic analysis; *v*) web searches. As a result of this empirical process of identification and validation of information, a database of 800 RSOs has been built in 2009. The primary data source was a structured questionnaire specifically designed by the authors in order to enable the reconstruction of each firm's history and particularly focusing on the firm's resources, products, market characteristics, employees and link with the parent institute. More specifically, the questionnaire was structured in different sections: business idea, technological innovation, financial support, human resources, competitors and networking, performance. The questionnaire was completed through Computer Assisted Telephone Interviews (CATI method)³ with either the founders or the Chief Executive Officers. A total of 291 interviews (36.1% on the population of RSOs identified in Italy in 2009) were carried out. To the purpose of our analysis, we matched cross-sectional data from the survey with economic and financial data collected from each firm's profit and loss accounts (Source: Bureau Van Dijk) to retrieve official and reliable data in two points in time: the year of foundation and the time of the survey. We run sample cleaning procedures by checking, identifying and removing inaccurate records from the dataset (i.e. removing outliers and excluding firms reporting unreliable information in their profit and loss account). The final sample used for the analysis consisted of 103 RSOs with available data for both the periods.

Similarly, to other studies in the field (c.f. Niosi, 2006) we chose to privilege the quality (i.e. to maximise the reliability) of the information collected on the RSOs included in the analysis as one of the most original elements in this work and this has resulted in a

² The present study has been funded by a national research project from the Institute for Industrial Promotion (IPI) aimed at realising a census activity of the population of RSOs in Italy.

³ CATI is a procedure which is frequently used to optimize the number of interviews according to the sample strata (in this case industry and location), and therefore to guarantee the generalizability of the results coming from the sample to the whole population of RSOs.

smaller sample. The use of multiple data sources was motivated by the need to avoid common method biases, that may have led to erroneous conclusions about the relationship between the independent variables and the dependent one. We thus privileged the reliability of the information collected on the RSOs to the use of a larger sample with less reliable information (i.e. information based on estimation procedures for outliers and missing data).

The descriptive statistics of both the target population of RSOs in 2009 (N=800) and in our sample (n=103), (Tables 1a- 1b) document the absence of significant differences with respect to the region of location of RSOs (North, Center, South) and the industries of operation.

	Population (%)	Sample (%)
North	52.6	57.3
Center	26.1	31.1
South	21.3	11.6
Avg. Age	4.2	3.8

	Population (%)	Sample (%)
Nanotech	4.1	6.8
Life Sciences	14.8	17.5
ICT	29.7	37.9
Energy and environment	16.8	13.6
Electronics	8.9	8.7
Industrial Automation	4.3	6.8
Innovation services	10.2	8.7
Other	11.2	-

Tables 1a-1b: Distribution of the target population (n=800) and the selected sample (n=103) of Italian RSOs with respect to the region and the industry of operation

Measures for outcome variables

A clear specification of the growth criteria adopted in this study is critical for the interpretation of the results and the comparison with other studies. In this respect, the occurrence of different results depending on growth measures adopted emphasizes the relevance of using multiple criteria (McDougall *et al.*, 1994). Firms' sales and employment are among the most used measures of growth and, in this study, they have been adopted as relevant outcome variables. Employment growth is important for policy makers in a job creation perspective, while revenues growth is the most diffused measure for small and new ventures (McDougall *et al.*, 1994; Delmar *et al.*, 2003). Another key issue is the specific type of revenues growth measure, since this aspect might be influenced by start-up size (Achtenhagen *et al.*, 2004). As used by a number of influential studies (Davis, Haltinwager, 1990; Davis *et al.*, 1996) the absolute growth measures (in revenues and employment) have been weighted for the average size observed between the two points in time (the year of foundation and the time of the survey).

Measures for predictor variables

We consider three dimensions which, within the RBV framework, have been found suitable to influence growth in RSOs: (i) technology, (ii) finance, (iii) human resources (management and entrepreneurship). For each of these dimensions, distinct predictor variables have been introduced in the model (Table 2).

Th. approach	H	Var. label	Var. description
RBV: Technology	1	IPR	Number of active patents owned at founding + active patents licensed at founding + trademarks owned at founding
RBV: Finance	2	VC	VC funds raised in the first year of operation (dummy)
RBV: Human resources (management and entrepreneurship)	3	RD_EX	Prior experience of one/promoting partners in R&D activities (dummy)
		PROD_EX	Prior experience of one/more

Th. approach	H	Var. label	Var. description
			promoting partners in production (manufacturing) (dummy)
		COMM_EX	Prior experience of one/more promoting partners in commercial activities (dummy)
		MGMT_EX	Prior experience of one/more promoting partners in a management function (dummy)
	4	PhD_sh	% of doctoral graduates over total employees (at founding)
	5	IND_PART	Presence of an industrial partner as a shareholder in the first year of operation (dummy)

Table 2. Predictor variables: link with theoretical approaches and research hypotheses, variable label, type and description

Measures for control variables

Table 3 reports a schematic representation of the measures adopted for control variables.

	Var. label	Var. description
Industry		Dummy variable indicating whether the firm is active in:
	NANO	nanotechnology and advanced materials
	INNOV	innovation services
	LIFE	life sciences
	ICT	ICT
	EN_ENVI	energy and environment
	ELECT	electronics
	MECH	advanced mechanics
Competitive forces	ENTRY	Barriers to entry at founding, ranging from: (0) = very low (very easy to enter) to (7) = very high (very difficult to enter)
	SUBS	Threat of substitutes, ranging from: (0) = not at all (no threats) to (7) = very high (very high threats)

	Var. label	Var. description
	BUY	Customers' bargaining power, ranging from: (0) = very weak to (7) = very strong
	SELL	Power of the suppliers of the firm, ranging from: (0) = very weak to (7) = very strong
Local context	CONTEXT	Supportive level of the local context to academic entrepreneurship, ranging from: (0) = not at all (low support) to (7) = very high (strong support)
R&D Investments	ΔRD_INV	Growth in R&D Investments
Firm age	AGE	Number of years since founding

Table 3. Control variables: variable labels, types and description

In order to assess the combinations of factors at founding that best represent growth determinants of RSOs, we developed an Ordinary Least Squares (OLS) regression analysis. The model specifications were the following:

(1) Employment growth:

$$\Delta EMPL = \beta_1 IPR + \beta_2 VC + \beta_3 XP + \beta_4 PhD_sh + \beta_5 IND_PART + \beta_6 COMP + \beta_7 CONTEXT + \beta_8 \Delta RD_INV + \beta_9 AGE + \beta_{10} INDUSTRY + \beta_{11} LOCATION$$

(2) Revenues growth:

$$\Delta REV = \beta_1 IPR + \beta_2 VC + \beta_3 XP + \beta_4 PhD_sh + \beta_5 IND_PART + \beta_6 COMP + \beta_7 CONTEXT + \beta_8 \Delta RD_INV + \beta_9 AGE + \beta_{10} INDUSTRY + \beta_{11} LOCATION$$

We tested the existence of non-linear associations between age of the firm and growth by including quadratic terms in the estimation. In order to avoid multicollinearity issues, the predictor variables and the control variables were centred on their means.

Results

Table 4 shows the results of the OLS regression models for

the two outcome variables. The results from the different growth measures adopted reveal a reassuring consistency. Predictor variables explain 70% of the variance in employment growth (R Squared for Δ EMPL model) and 65% of revenue growth (R Squared for Δ REV model).

The results of the multivariate analysis show that RSOs growth paths, both in terms of employees and revenues are different at different ages. The coefficient of AGE_sq is positive and highly significant in both the models, while the coefficient of AGE is negative and significant in Model 2. Therefore, we can assume that both the models are able to predict long-term growth, rather than early growth.

With respect to our hypotheses, we find that firm conditions at founding have a significant impact on RSOs growth paths, but not necessarily in the expected direction. Moreover, different conditions impact RSOs growth if measured in terms of employees or in terms of revenues.

Th.approach	H	Var- names	Model 1: Δ EMPL		Model 2: Δ REV	
			Coeff. (SE)	Sig.	Coeff.(SE)	Sig.
RBV: Technology	1	IPR	-0.159 (0.104)	0.129	16570.3 (14196.7)	0.247
RBV: Finance	2	VC	2.227* (0.897)	0.014	246989.7* (119371)	0.042
RBV: Human resources (manageme nt and entrepreneu rship)	3	RD_XP	-1.239* (0.580)	0.036	-37713.2 (80154.1)	0.639
		PROD_ XP	-0.167 (0.580)	0.756	50744.1 (72028.6)	0.483
		COMM_ XP	0.814 (0.619)	0.192	176957.5* (83590.8)	0.037
		MGMT_ XP	-0.625 (0.634)	0.327	-45764.7 (85997.3)	0.596
	4	PhD_sh	-0.036a (0.018)	0.054	-975.6 (2541.3)	0.702
	5	IND_ PART	0.159 (0.437)	0.716	-9525.84 (59923.4)	0.874
Comp. forces	ENTRY		-0.040 (0.122)	0.741	-8096.14 (16649.7)	0.628
	SUBS		-0.095 (0.112)	0.397	-15568.2 (17066.9)	0.647
	CUST		-0.004 (0.125)	0.973	-16401.5 (17414.84)	0.365

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	SUPPL	0.042 (0.106)	0.693	32957.9* (14206.8)	0.023
Local context	CONTEXT	0.053 (0.097)	0.585	-4028.3 (13345.5)	0.764
Δ R&D Inv.	RD_INV	0.005a (0.003)	0.057	1779.18*** (373.8)	0.000
Firm's age	AGE	0.012 (0.105)	0.909	-25156.7a (14192.1)	0.080
Firm's age (squared)	AGEsq	0.016** (0.004)	0.001	3032.8*** (616.9)	0.000
Industry	NANO	0.869 (1.007)	0.391	-67494.2 (145774.5)	0.645
	LIFE	0.917 (0.707)	0.198	6988.1 (102730)	0.946
	ICT	0.884 (0.643)	0.173	15832.7 (95903.4)	0.869
	EN_ENVI	0.383 (0.742)	0.606	-15705.1 (105913.1)	0.883
	ELECT	0.415 (0.887)	0.641	146436.8 (125199.9)	0.246
	Var-names	Model 1: Δ EMPL		Model 2: Δ REV	
	IND_AU	1.187 (1.074)	0.272	-113242.3 (151137.7)	0.456
	INNOV	(baseline)		(baseline)	
Location	NO	0.642 (0.581)	0.272	11433.3 (80132.7)	0.887
	CEN	1.045a (0.622)	0.097	76585.9 (85541)	0.373
	SO	(baseline)		(baseline)	
R-squared		0.703		0.649	
F-ratio		7.80***		5.94***	
n		103		101	

Table 4– Results of the regression models for RSOs growth

(Standard errors are reported in parentheses) (●) $p < 0.1$ (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$

RBV: Technology

Adding to what recently highlighted by Ferri et al. (2019) about the impact of patenting activities on RSOs' early performance, our results indicate that technology capital (i.e. the stock of IPRs owned by RSOs at founding) does not significantly affect RSOs long-term growth in terms of employment nor in terms of revenues (the coefficient of IPRs being not significant in both the models), leading to reject H1.

We find that persistence in R&D investments [RD_INV], rather than the strength of the technological endowment at founding, has a strong and positive impact on RSOs' revenues growth ($p < 0.001$) and a weaker (but still significant) impact on employees' growth ($p < 0.1$). We conclude that R&D-investing RSOs grow in terms of employees and (most of all) in terms of revenues even if their activities in the market for technology are not persistent. This assumption is further confirmed by the fact that 43% of the RSOs in the sample do not hold IPRs during the first five years of operation.

RBV: Finance

H2 is accepted, since we register a significant difference in terms of growth between VC-backed and non-VC-backed RSOs groups in both the models ($p < 0.05$). This result is in line with recent empirical studies (Bock et al., 2018; Marullo et al., 2018a) demonstrating that VC funds, more than other types of financial resources, are one of the most significant predictors of new ventures' success. Notwithstanding the role of financial capital resources in fostering the exploitation of academic research to the market, more attention should be paid to the role that VC funds play in different stages of RSOs development.

RBV: Human resources: management and entrepreneurship

H3 is partially accepted. The regression coefficient of [RD_XP] is negative and significant in model 1 ($p < 0.05$), indicating that RSOs whose promoting partners exhibited previous experience in R&D (i.e. "senior researchers") grow significantly less in terms of employees. At the same time, evidence from model 2 shows that previous experience ripened by the promoting partners in the commercial [COMM_XP] function significantly affects revenues growth ($p < 0.05$). These results are consistent with evidence provided by prior literature (Roberts, 1991; Cooper et al., 1994), supporting the conclusion that market orientation, rather than research orientation

itself, allows RSOs to benefit from a superior economic performance (Abbate, Cesaroni, 2017). Largely in line with the consideration that RSOs' long term growth is supported by persistent R&D investments and strong commercial orientation, we conclude that after entry and in later stages of firm development founding teams with large R&D experience could purposefully limit employees' expansion to privilege growth in terms of revenues (i.e. the exploitation of new products to the market).

By contrary, H4 is rejected. Consistent with prior literature in the field of entrepreneurship, our results do not provide statistical support to the hypothesis that the level of entrepreneurs' education itself is a determinant of growth in RSOs. In line with the results discussed before, highlighting the importance of balancing R&D experience and commercial orientation in RSOs, a large share of doctoral graduates over total employees in the year of foundation is likely to produce a negative effect on growth in terms of employees ($p < 0.1$), while it will have scarce or no effect on long term revenues growth. Although equity alliances and corporate VC represent growth opportunities for small companies, industrial partnerships with RSOs operating in science-based sectors could be undermined by increased complexity, unbalanced market power and information asymmetries between large firms and their smaller counterparts (Lokshin et al., 2011; Marullo et al., 2018b). Establishing industrial partnerships and/or calling upon external managers has been frequently proposed as a solution to bridge the gap between cultures, competencies, and attitudes of researchers and businesspeople (Wright et al., 2007). Nonetheless, the formal involvement of an industrial partner [IND_PART] does not significantly affect long-term growth. This finding confirms and underlines the limits of "traditional" industrial partnerships for a kind of firm like an RSO (Benghozi, Salvador, 2014). H5 is therefore rejected.

Control variables

Concerning competitive forces, a positive significant effect of suppliers' bargaining power [SUPPL] on the growth of RSOs in terms of employment can be observed. Those firms which at founding encountered higher level of suppliers' bargaining power tend to grow

more in terms of number of employees than the RSOs which entered markets without such characteristic. As Agarwal et al. (2004) observed, interaction with industry through partnerships is more effective than knowledge acquisition through hiring experienced employees.

With regard to the context, the support provided by the local environment in which RSOs are embedded [CONT] seems to show a positive effect on growth in terms of employees and a negative effect on growth in terms of revenues. No conclusions were made in this respect, since the estimations were found as not significant in both the models. Finally, no significant industry effect was found in the two models of RSOs growth.

Discussion and conclusion

In the last decades RSOs have attracted significant attention. Nevertheless, empirical evidence has shown that just a small percentage of them exhibit solid growth paths, whereas most of them tend to be stagnant.

This paper aimed at contributing to the debate about the growth or non-growth of RSOs through the identification of the critical variables determining long-term growth processes of such peculiar firms. Our results indicate that the size of the IPRs portfolio and the formal involvement of an industrial partner among the company's shareholders at founding do not significantly affect RSOs' growth in terms of employees and revenues. By contrary, the formal involvement of a VC among the shareholders and the presence of experienced people in the commercial function represent a determinant of RSOs long-term growth. Furthermore, a positive relationship between R&D investments and growth (in terms of both revenues and employees) emerges. In particular, the lack of influence of IPRs on growth suggests that the strong scientific and technical background held by RSOs is probably valorised in terms of non-patentable knowledge, which can be understood since RSOs often license IPRs from mother organizations and do not own patents since their very early stages. RSOs must be considered as "creative" firms (Greiner, 1972) holding specific knowledge not includable in the traditional outputs of IPRs.

Secondly, VC emerges from the analysis as an important

determinant of growth. Wright et al. (2006) highlighted that VC is seen as a solution to fill the equity gap of RSOs, even if VCs prefer to invest only after the seed stage. This confirms the role of VCs not only in providing financial resources but also, most probably, in providing useful indications about how to compete in fast evolving markets.

Thirdly, regarding previous founders' experiences, we found that managerial and entrepreneurial experience are important growth determinants. If it is true that RSOs have strong scientific and technological background, it is also known that a major failure cause is insufficient managerial and commercial skills (Franklin et al., 2001). It is true that, on the basis of the same belief, the scarce influence on growth coming from the involvement of an industrial partner is a bit surprising. Most probably, RSOs – in their early stages – are often involved in developing general purpose technologies and the involvement and contribution of industrial firms do not result to be neither easy nor particularly effective. At least, not as effective as those from VCs. Nevertheless, this result confirms the challenges of traditional industrial partnerships when it comes to small firms operating in science-based sectors (Marullo et al., 2018b). As also highlighted by Benghozi and Salvador (2014), industrial partnerships should rather be conceived, for firms like RSOs, in the form of a set of industrial relations between RSOs themselves (i.e. the structure and embeddedness in a business ecosystem).

Our study is not free of limitations. It focuses on a sample of RSOs from a single country. A positive side-effect of analysing a national geographic coverage over a large time span is that this reduces the influence of non-measured variance and it contributes to strengthen the external validity and generalizability of the results. Panel data analysis could further confirm and enrich the results from our investigation. Future research should deepen the analysis of RSO growth issue, by investigating its links with the literature about RSO survival, failure and throughout different stages of development (Greiner, 1998).

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