



# Unpacking liabilities of newness and smallness in innovative start-ups: Investigating the differences in innovation performance between new and older small firms

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## ABSTRACT

New ventures face both liabilities of newness and smallness, which may inhibit their innovation efforts and output. However, existing research has not clearly distinguished between the two liabilities, leaving it unclear how certain determinants differentially affect innovation performance in start-ups relative to older established small and medium sized enterprises (SMEs). Therefore, in this study we investigate the impact of R&D investments, external knowledge sourcing and public R&D subsidies on innovation effectiveness in new versus older small firms. Employing panel data from the Spanish Community Innovation Survey (CIS), we show that R&D investments have a lower contribution to the innovation performance of new ventures, compared to older small firms. In contrast, we find that external knowledge sourcing makes a higher contribution to the innovation performance of new compared to older small firms, but only in high-tech settings. However, we find no support for a differentiating effect of R&D subsidies in new versus established small firms. Effectively, our results highlight the limited effects of internal R&D investments and R&D policy instruments to promote the growth of innovative start-ups, while highlighting potential benefits of their openness to external sources of innovation. As such, these results have important implications for research, practices and policies that relate to innovation in new ventures and SMEs, while casting doubts on the effectiveness of some of the common strategy and policy instruments to stimulate performance in small innovative start-ups.

## 1. Introduction

The literature on economic growth in the last ten years has recognized that small innovative start-ups are the cornerstone of the Schumpeterian creative destruction process and one of the main drivers of economic growth (Wiklund and Shepherd, 2005; Schneider and Veugelers, 2010). Compared to older firms, innovative start-ups have to deal with the liability of newness, meaning the difficulties of new organizations to compete effectively against established organizations (Stinchcombe, 1965). These difficulties are explained by the fact that start-ups need some time to learn to define efficient routines and to create a solid structure (Bruderl and Schussler, 1990) and have low levels of legitimacy and unstable links to customers, suppliers and partners (Freeman et al., 1983). In addition to newness, small innovative start-ups also have to deal with the liability of smallness, which is the lack of resources necessary to effectively deploy the routines and structure required to implement their strategy.

Current research on innovation performance does not clearly distinguish the different impacts of the liability of newness and smallness on the innovation performance of small innovative start-ups. On one hand, a large stream of research has studied the innovative performance of start-ups, but it has seldom compared the performance of small start-ups and small older innovative firms. On the other hand, some research has also focused on the innovative performance of small firms without discriminating between older and younger firms. To add to this confusion, the impact of public innovation policies on newness and smallness are still largely unknown (Grilli, 2014). In fact, most of the policy instruments to foster innovation in SMEs, such as SME instrument in Europe or the Small Business Innovation Research (SBIR), do not distinguish between small old firms and start-ups and aim to solve the liability of smallness through public funding rather than tackling the newness challenges in start-ups.

The main goal of our study is to shed some light on the differences between smallness and newness in terms of the effectiveness of innovation in small innovative start-ups. We do this by drawing on the knowl-

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edge spillover theory of entrepreneurship, which emphasizes that a context with more endogenously created knowledge results in knowledge spillovers, which in turn create more entrepreneurial opportunities (Audretsch and Keilbach, 2007; Acs et al., 2009). We test our hypotheses using panel data from the Spanish Community Innovation Survey (CIS), and we specifically investigate the impact of R&D investments, the diversity of external knowledge sourcing and public R&D subsidies on innovation effectiveness of start-ups compared to older innovative small firms. We find that compared to older firms, in knowledge-intensive environments such as high-tech industries, R&D investments make a lower contribution to the innovation performance of start-ups. We also find that compared to older firms in high-tech industries, diverse external knowledge sources contribute more to innovation performance in start-ups. At the same time, we find no differential effect for the use of R&D subsidies.

Our research therefore suggests that innovative start-ups focusing on overcoming newness liability through external knowledge sourcing strategies will have a better innovation performance than those focusing on overcoming smallness liability through R&D resource accumulation, while the effect of the use of R&D subsidies remains similar for both firms. We did not find significant differences between new and older firms in less knowledge intensive industries, which confirms that underlying mechanisms of knowledge spillover entrepreneurship take place in knowledge intensive industries. The main theoretical contribution of the paper is to strengthen the links between literatures on entrepreneurship, SMEs, open innovation and public policy (Acs et al., 2013; Spithoven et al., 2013; Colombelli et al., 2016; Bogers et al., 2017). Our findings have important implications not only for innovative small and new ventures per se but also for public policy, since it explains that start-ups will benefit more from policy instruments that support external knowledge orientation rather than focusing on monetary terms.

Below, we first present the theoretical framework and corresponding hypotheses. Next, we explain the empirical research methodology and sample, followed by the results. In the last two sections, we discuss our findings and summarize the main theoretical, empirical and managerial implications as well as the limitations and future research directions.

## 2. Theoretical framework

### 2.1. Effectiveness of R&D investments in new ventures

According to the knowledge spillover theory of entrepreneurship, start-ups tap business opportunities from knowledge which is rejected or ignored by incumbent firms (Audretsch and Keilbach, 2007; Acs et al., 2013). The underlying mechanism refers to innovation patterns in the Schumpeter Mark I and Schumpeter Mark II models (Nelson and Winter, 1982; Breschi et al., 2000). On the one hand, Mark I model represents the concept of knowledge widening as an institutional innovation pattern where new ventures enlarge the existing knowledge base and erode the competitive advantages of large firms. On the other hand, the Mark II model represents knowledge deepening as an innovation pattern where large corporations drive the development of innovation through R&D investments and cumulative knowledge development. While intramural R&D investments are central for performance in the face of knowledge deepening (Cohen and Levinthal, 1989), the link between R&D investments and innovation performance is not straightforward in the face of knowledge widening. While innovative start-ups play a critical role in the Mark I model, current research proposes contradicting arguments related to the differences in terms of effectiveness of R&D investments between older and younger firms.

There are theoretical arguments supporting both positive and negative relationships between newness and innovation performance. On

the one hand, newness may represent an advantage for new ventures. They will be more flexible than older firms because of more flexible business models (Kapoor and Klueter, 2015), will have fewer limitations in terms of technological trajectories based on their lower risk aversion or ‘the knowledge filter’ (Audretsch and Keilbach, 2007), will suffer reduced cognitive distance between the existing knowledge base and emerging technologies (Tripsas and Gavetti, 2000), or fewer constraints in terms of adapting innovation routines and organizational structures (Collinson and Wilson, 2006). However, the empirical evidence does not confirm the positive relationship between R&D investments and innovation performance in start-ups. While an earlier meta-analysis revealed inconclusive evidence on the role of R&D investments on start-ups’ success, Coad et al. (2016) and Capasso et al. (2015) showed more recently that only high growth start-ups, which are a small proportion of start-ups, benefit from higher R&D investments. Similarly, Kotha et al. (2011) observed that newer firms produced a lower amount of innovation output, and Jha and Bose (2016) showed that intramural R&D activities had a positive impact on product innovation only on large corporations, not on younger firms. In fact, the effectiveness of R&D investments is less contingent on firm size but more on R&D experience (García-Quevedo et al., 2014; Braunerhjelm et al., 2018).

On the other hand, while the knowledge spillover theory of entrepreneurship posits that entrepreneurial opportunities are more widely available in the face of knowledge spillovers (Audretsch and Keilbach, 2007; Acs et al., 2013), the extent to which start-ups are able to leverage this knowledge may be constrained by some of their liabilities of newness (Freeman et al., 1983; Bruderl and Schussler, 1990). Start-ups will need time to dynamically learn how to improve their organizational routines aimed at searching, acquiring and exploiting knowledge (Nelson and Winter, 1982; Rosenkopf and Nerkar, 2001) and to accumulate internal knowledge and build absorptive capability (Cohen and Levinthal, 1989). Thus, we argue that the negative impact of lack of experience in start-ups prevails over the benefits of flexibility, because of the dominance of the time dependence logic of organizational learning and absorptive capabilities. Since start-ups would need time to build a cumulative path-dependent learning process, they will invest in R&D more inefficiently than older firms. We therefore suggest that compared to older innovative small firms, the innovation output of innovative start-ups will be less dependent upon the in-house R&D investments.

*Hypothesis 1: Compared to older innovative small firms, the effectiveness of R&D investments will be lower in innovative small start-ups.*

### 2.2. Effectiveness of diverse external knowledge sources in innovative start-ups

Product innovation does not only rely on internal R&D investment; it also typically benefits from external knowledge sourcing (Cassiman and Veugelers, 2002; Laursen and Salter, 2006; Gimenez-Fernandez and Sandulli, 2017). While open innovation has been typically explored as a way for large firms to capture knowledge spillovers across organizational boundaries (Chesbrough and Bogers, 2014), the internal characteristics of small firms will imply particular mechanisms for how this process may take place (Spithoven et al., 2013; West and Bogers, 2014; Eftekhari and Bogers, 2015). There are some theoretical arguments supporting that, compared to established firms, innovative start-ups may benefit more from external knowledge sourcing.

First, according to the theory of knowledge spillover entrepreneurship, external knowledge is an important source of entrepreneurial opportunities that will be more likely grasped by start-ups than by established firms since start-ups serve as a conduit of ideas and knowledge created in one organizational context, but left uncommercialized be-

cause of its uncertainty (Audretsch and Keilbach, 2007). Thus, start-ups are able to tap an entrepreneurial opportunity knowledge that otherwise would remain wasted. Second, start-ups are more likely to compete in environments where knowledge is more fluid and has typically fuzzy boundaries (Hess and Rothaermel, 2011) and where innovation is more driven by the fusion of interrelated capabilities than by the accumulation of technological capabilities (Cantwell and Santangelo, 2000). In these environments, start-ups will be more likely to enter knowledge exploration alliances compared to exploitation alliances and ultimately internal R&D investment (Rothaermel and Deeds, 2004). Third, since start-ups typically aim at more rewarding opportunities (Mindruta, 2013), they will more easily build alliances. Fourth, in start-ups, external knowledge sourcing will be a stronger driver of organizational learning because it will reduce the risk associated to high technological uncertainty or changing market conditions (Liebeskind et al., 1996; Zahra and Bogner, 2000). Fifth, start-ups will suffer lower levels of internal resistance to absorb external knowledge, because in start-ups external knowledge does not have to compete with internal knowledge spillovers resulting from knowledge accumulation over firms' lifetime (Acs et al., 1994). Finally, start-ups are more likely to use external knowledge because they compete in terms of development of new standard base technologies, compared to proprietary technologies that are built upon internal knowledge capabilities (Henderson, 1999).

Former empirical evidence supports the positive relationship between external sourcing and innovative performance of start-ups (Dowling and McGee, 1994; Baum et al., 2000; Pellegrino et al., 2012; Protogerou et al., 2017). However, this evidence also suggests that effectiveness of external knowledge sourcing is related to cooperation breadth, defined as the array of external knowledge sources (Laursen and Salter, 2006). Using diverse knowledge sources may mitigate the risks related to unfamiliar markets or technologies. In fact, start-ups prefer to learn across multiple technological trajectories instead of learning within one technological trajectory (Rosenkopf and Nerkar, 2001). Moreover, start-ups may be willing to cooperate with different partners in order to share the costs and risks involved in innovation activities (Van de Vrande, 2013). Finally, compared to established firms, start-ups did not have time to develop strong alliance capabilities and therefore they would prefer to enter heterogeneous cooperations to avoid getting trapped by redundant knowledge (Dell' Era and Verganti, 2010) or opportunistic behaviors (Colombo et al., 2006). Accordingly, we suggest that the innovation output of small innovative start-ups will be higher when they rely on a broader range of external knowledge sources.

*Hypothesis 2: Compared to older small innovative firms, the innovative effectiveness of broader range of external knowledge sourcing will be higher in innovative small start-ups.*

### 2.3. Effectiveness of R&D subsidies in new ventures

The nature of knowledge as a public good (non-rivalrous and non-excludable) in the knowledge spillover theory of entrepreneurship (Audretsch and Keilbach, 2007) and open innovation literature (Bogers, 2011; Laursen and Salter, 2014) means that firms may not be the only ones to benefit from the value created by their innovative activities. Therefore, firms may underinvest in R&D, which is particularly evident in small firms, and governments could offer subsidies in order to alleviate this problem (Hall and Lerner, 2010; Meuleman and De Maeseneire, 2012). The logic here is that they increase the survival odds and growth opportunities of existing firms while they also guarantee a large enough knowledge base to enable entrepreneurial activity and the birth of new firms (Acs et al., 2013).

Most of the literature has focused on the relationship between R&D subsidies and R&D expenditure, but studies looking at the impact of

R&D subsidies on new firm performance (Grilli, 2014; Dimos and Pugh, 2016) are scarce. The existing evidence casts some doubt on the effectiveness of R&D subsidies, such as when Koga (2005) observes that R&D subsidies complement internal R&D only for mature high-tech firms. More generally, other studies point to a lack of support for the relation between R&D subsidies and the performance of small young firms (Blanes and Busom, 2004; Schneider and Veugelers, 2010). More specifically, Colombo et al. (2013) show that automatic R&D subsidies have no impact on new firm performance compared to selective subsidies, while Antolín-López et al. (2015) show that new small ventures benefit more from policies aimed at encouraging R&D cooperation, while large corporations benefit more from tax reduction for R&D expenditures and direct R&D subsidies.

Some further explanations for the lack of relationship between R&D subsidies and the performance of new small firms may lie in organizational learning limitations (Aldrich and Yang, 2014). Hussinger (2008) also points to this role of organizational learning, since the lack of experience with receiving public R&D subsidies may also limit the impact of this policy on innovation performance. Hence, the low absorptive capability and the lack of well-established innovation routines may explain the failure of direct R&D subsidies to start-ups. For these reasons, we would expect R&D subsidies to be less effective in the innovation strategies for small innovative start-ups than for older innovative firms.

*Hypothesis 3: Compared to older small firms, the innovative effectiveness of R&D subsidies will be lower in small innovative start-ups.*

## 3. Methodology

### 3.1. Sample

To empirically test our model and to isolate the effect of newness from smallness on innovation effectiveness this research uses SMEs' and start-ups' data from the Spanish Technological Innovation Panel database (PITEC), collected by the Spanish National Statistics Institute (INE). PITEC is based on the core Eurostat Community Innovation Survey (CIS), and it enables the study of innovative Spanish firms over time. PITEC is a representative dataset of the population of Spanish firms, collecting data on a yearly base from 2003. However, in 2004 PITEC introduced some important changes in the questionnaire, affecting variables related to cooperation with external sources for technology innovation, which are central variables in this study. Due to these limitations, this study uses data from 2004 to 2013. We restrict our attention to innovative firms, those intended to have an innovation activity, even if they failed. This selection is driven by the aim of the underlying call for papers: innovative start-ups and policy initiatives. Moreover, it should not be problematic since former evidence argues that there is not an important selection bias when using only R&D performers to analyze the relationships between R&D activities and performance (Barge-Gil and López, 2015).

As we are mainly interested in the effects of different policy initiatives on the innovative performance of SMEs versus start-up companies, our sample consists of two subsamples: innovative SMEs and small innovative start-ups. Our definition of an SME is based on that used by the European Commission and the OECD (2005), which use a cut-off of 250 employees. Regarding the definition of a start-up, there is no consensus in the literature, so we opt to follow the definition provided in the survey that includes those firms not more than three years old. This cut-off of three years has also been used in the literature (e.g. Bosma et al., 2004; Laursen and Salter, 2006; Bhalla and Terjesen, 2013). We therefore define our subsample of small innovative start-ups by picking those firms that started to perform innovative activities, to be less than three years old and with fewer than 250 employees in 2004, and then we gather their longitudinal data. We identified some outliers that were withdrawn from the sample. In total, the

sample consists of 37,655 observations –35,726 observations from SMEs and 1929 from start-ups.

The regressions show a smaller number of observations due to the drop in one-year observations when introducing lagged terms.

### 3.2. Measures

#### 3.2.1. Dependent variables

This paper analyses the impact of different contexts to bring innovations to the market. A well-established proxy for innovation performance is revenue from product innovation, which has been used in the SME context (e.g. Spithoven et al., 2013), as well as in the start-up context (e.g. Criscuolo et al., 2012). In the questionnaire, firms are asked to assert what share of their sales can be ascribed to innovations to market. Hence, innovation performance is measured as the share of turnover resulting from new or strongly improved products that the company introduced to the market and that were new to the market during the last three years.

#### 3.2.2. Independent variables

This study considers the effect of three different factors –R&D intensity, cooperation breadth, and R&D subsidies- to explain the difference in innovation performance in innovative start-ups related to innovative SMEs. First, scholars consider R&D intensity to be crucial for innovation (Lin, 2003; Schmiedeberg, 2008), and it is a proxy for absorptive capacity (Cohen and Levinthal, 1990). R&D intensity is computed as the ratio between total expenses in internal R&D and number of employees (Mairesse and Mohnen, 2004; Barry, 2005). We take the natural logarithm to compensate for the differences in innovation expenses between firms. We create the interaction variable R&D intensity and start-up to test if the impact of internal R&D expenses is lower or higher in start-ups related to SMEs.

Second, to measure the degrees of external knowledge sourcing the research uses the widely employed construct of cooperation breadth, which is defined as the number of different types of sources with which a firm cooperates (Laursen and Salter, 2006). In the survey, firms are asked if they cooperated with the following categories of external sources in the last three years: suppliers, customers (private and public sector), competitors or other firms from the same activity field, consultants or commercial laboratories, universities or other higher education institutes, public or private research centres and technological centres. Following the methodology of Laursen and Salter (2006), the variable cooperation breadth is constructed as the sum of those seven cooperation partners. Each of the seven cooperation partners is coded as a binary variable, 1 if the firm cooperated with a given partner category, and 0 otherwise. Subsequently, the seven types of cooperation partners are added up so that each firm gets a 0 when no cooperation agreements with any type of partner were taken, and 7 when it cooperated with all the different types of partners. Empirical literature has found that the relationship between cooperation breadth and innovation performance has an inverted-U shape (Laursen and Salter, 2006; Oerlemans et al., 2013; Leeuw et al., 2014). Therefore, to test the linearity of cooperation breadth, we include its squared value. We create the interaction term cooperation breadth and start-up to test whether there are greater benefits of using heterogeneous external knowledge sources in start-ups.

Third, R&D subsidies refers to public funding to support firms' R&D activities. Literature has measured this variable both as a binary variable (e.g. Segarra-Blasco and Arauzo-Carod, 2008; van Beers and Zand, 2014) or a continuous variable (e.g. González et al., 2005; García-Quevedo et al., 2014). In this study we follow a continuous approach, so R&D subsidy ranges from 0 to 100 since it is measured as the ratio of total public subsidies to total R&D expenses (González et al., 2005). We create the interaction term R&D subsidy

and start-up to test whether there are greater benefits in using this strategy on start-ups.

#### 3.2.3. Control variables

In order to rule out possible alternative explanations to those formally hypothesized, the model includes the following control variables.

First, we control for firm size as it has been argued as relevant for firms' innovative behavior (Audretsch et al., 2000; Berchicci, 2013). This allows us to control for the effects of the liability of smallness from our analysis, while focusing directly on the feature of newness (Criscuolo et al., 2012). This variable is measured by the logarithm of the total number of employees.

Second, we include a dummy variable (Belderbos et al., 2004; van Beers and Zand, 2014) to control if the firm belongs to a group because firms belonging to a corporate group could bring knowledge from the large corporation and be more innovative (Criscuolo et al., 2012).

Third, we include as a control variable the scope of the market where the firm sells its products since it would increase the firm's market share. It is measured by the sum of the involvement in different markets: local, national, European, and other international markets (Laursen and Salter, 2014).

Fourth, a significant factor in shaping innovative activities is the formal appropriation strategy of the firm (Alkaersig et al., 2015; Gans and Stern, 2003). Firms need to protect their innovations and deploy suitable appropriation strategies against imitation, as well as avoid intentionally or unintentionally allowing partners to collect all the benefits. Following Laursen and Salter (2014) methodology, we include the variable formal appropriation strategy, meaning the sum of the different appropriation mechanisms that a firm uses. The variable is therefore measured by the sum of the use of the four appropriation mechanisms -patents, trademarks, copyright, and design rights-. These items are binary variables, being 1 if the firm registered or applied it during the last three years, and 0 if it did not; and it obtains the value of 4 when all the mechanisms were used by the firm, and 0 if it did not use any of them.

Fifth, the literature has discussed that firms operating in knowledge-intensive sectors are more likely to open their boundaries (Schroll and Mild, 2011). We measure the intensive technology sectors through a dummy variable that indicates if the firm belongs to a high-tech sector (Luker and Lyons, 1997). We follow the Spanish National Statistics Institute classification to determine the firms that operate in a high-tech sector. In particular, this classification considers as high-tech sectors the following: Pharmaceuticals, Manufacturing of IT, Electric, Medical Equipment, Aerospace, Chemical Industry, Motor Vehicle Manufacturing, IT Services, Telecommunications and R&D Services.

Sixth, we introduce a dummy variable regarding process innovation to control for other technological innovations of firms. It takes the value one if the firm reports having introduced process innovations (Barge-Gil and López, 2014). Finally, we have included year dummy variables to control time trends.

A short description of the variables used to test the model and their references are included in Table 1.

## 4. Results

### 4.1. The innovative effectiveness of R&D investment, external knowledge, and subsidies

Tables 2-4 report the basic statistics of the variables used in the analysis. Regarding the innovation performance, we observe that the proportion of income coming from new products is larger in start-ups than in SMEs. Most of the firms have a closed innovation model (the average number of external cooperation sources is 0.8); however, cooperation breadth grows over time. Moreover, compared to SMEs, start-

**Table 1**  
Variable description.

Variable	Description	References
Innovation performance	Proportion relative to turnover of new or strongly improved products that the company introduced to the market and that were new to the market.	Belderbos et al. (2004); Faems et al. (2010); Nieto and Santamaría (2007)
Start-up	Dummy variable to indicate whether the firm is a new creation	Laursen and Salter (2006)
R&D intensity	Natural logarithm of the ratio of internal R&D expenditure related to number of employees	Barry (2005); Mairesse and Mohnen (2004)
Cooperation Breadth	Sum of seven cooperation partners: suppliers, customers (private and public sector), competitors or other firms from the same activity field, consultants or commercial laboratories, universities or other higher education institutes, public or private research centres and technological centres.	Laursen and Salter (2006, 2014)
R&D subsidies	Ratio of public funding to innovation expenses	González et al., (2005)
Size	Natural logarithm of the total number of employees.	Audretsch et al. (2000); Berchicci (2013)
Group	Dummy variable to indicate if the firm belongs to a firm group.	Criscuolo et al. (2012)
Scope	Sum of the involvement in different markets: local, national, European, and other international markets.	Laursen and Salter (2014)
Formal approp. strategy	Sum of the use of the four appropriation mechanisms: patents, trademarks, copyright, and design rights.	Laursen and Salter (2014)
High-tech	Dummy variable to indicate whether the firm belongs to a high-tech sector.	Luker and Lyons (1997)
Process innovation	Dummy variable to indicate whether the firm has introduced a process innovation	(Barge-Gil and López, 2015)
Year	A set of dummy variables for the observation year.	Un et al. (2010); Wang et al. (2013)

**Table 2**  
Descriptive statistics in 2004.

Variable	Obs	Mean	Std. Dev.	Min	Max
Innovation performance	5424	10.12	22.60	0	100
R&D intensity	5424	10,071.41	27,745.72	0	778,263.7
Cooperation breadth	5424	0.80	1.41	0	7
R&D subsidies	5424	9.11	20.25	0	100
Start-up	5424	0.06	0.23	0	1
Size	5424	58.89	59.80	1	249
Group	5424	0.27	0.45	0	1
Scope	5424	2.87	1.03	1	4
Formal approp. strategy	5424	0.64	0.96	0	4
High-tech	5424	0.31	0.46	0	1
Process innovation	5424	0.63	0.48	0	1

ups rely on a larger number of knowledge sources (on average, 1.24 sources in start-ups vs 0.78 in SMEs). Start-ups also rely more on public funding, which provides around 19.15% of the innovation expenses for

**Table 3**  
Descriptive statistics in 2004. Subsample SMEs.

Variable	Obs	Mean	Std. Dev.	Min	Max
Innovation performance	5118	9.42	21.41	0	100
R&D intensity	5118	8,838.68	25,121.19	0	778,263.7
Cooperation breadth	5118	0.78	1.38	0	7
R&D subsidies	5118	8.51	19.57	0	100
Start-up	5118	0.00	0.00	0	0
Size	5118	61.23	60.25	1	249
Group	5118	0.28	0.45	0	1
Scope	5118	2.92	1.02	1	4
Formal approp. strategy	5118	0.62	0.95	0	4
High-tech	5118	0.29	0.45	0	1
Process innovation	5118	0.64	0.48	0	1

**Table 4**  
Descriptive statistics in 2004. Subsample start-ups.

Variable	Obs	Mean	Std. Dev.	Min	Max
Innovation performance	306	21.81	35.39	0	100
R&D intensity	306	30,689.42	51,460.44	0	423,923
Cooperation breadth	306	1.24	1.69	0	7
R&D subsidies	306	19.15	27.55	0	100
Start-up	306	1.00	0.00	1	1
Size	306	19.76	32.52	1	226
Group	306	0.22	0.42	0	1
Scope	306	2.09	0.89	1	4
Formal approp. strategy	306	0.90	1.01	0	4
High-tech	306	0.61	0.49	0	1
Process innovation	306	0.58	0.49	0	1

start-ups, and 8.51% for SMEs. Internal R&D intensity differs between start-ups (30,689.42 €) and SMEs (8,838.68 €) and these differences are consistent across industries. Table 5 shows sample breakdown by industry.

Table 6 shows the correlation coefficients of the variables (except year dummies). The three independent variables are positively correlated to the dependent variable. Furthermore, innovation performance positively relates to start-ups positively and high-tech firms. None of the correlations are sufficiently strong to suggest multicollinearity problems. In addition, we conducted a variance inflation factor (VIF) test. All the VIFs are lower than 4, and the average VIF is 1.60, indicating few problems of multicollinearity. Nevertheless, before calculating the interaction terms, we first standardize the independent variables to reduce or eliminate any bias, and then form the cross-product terms.

Following the approach of similar research (Laursen and Salter, 2006), we considered a censored Tobit model to deal with the large number of observations censored to the left. However, recent research on innovation performance has to deal with the initial conditions problem, which is the result of the correlation between unobserved heterogeneity and past values of innovation performance (Raymond et al., 2010). This problem will be present when the start of the observed panel data set does not coincide with the start of the stochastic process. In our sample, in the case of small innovative start-ups initial values are non-stochastic constants because the start of the dataset coincides with the year these firms were born. However, since we are also observing in our sample small innovative older firms born before 2004, we should specify the conditional distribution of initial values for these firms. Former research has solved this problem by adopting a random effects approach and more specifically employed dynamic Tobit models (Akay, 2012). Therefore, we apply a dynamic Tobit model

**Table 5**  
Number of firms by sector in 2004.

Sector	Start-ups	SMEs	Total
Agriculture	4	91	95
Extraction industry	2	23	25
Food and beverages	18	348	366
Textile	5	154	159
Clothing and fur industry	0	33	33
Leather and shoe industry	0	46	46
Wood and cork	0	52	52
Paper	1	48	49
Publishing, graphic arts and reproduction	2	56	58
Chemical industry	13	417	430
Pharmaceutical industry	6	83	89
rubber and plastic products	5	204	209
tire and glazed ceramic	0	26	26
Mineral product non-metallic	3	149	152
Ferrous metallurgical products	1	42	43
Non-ferrous metallurgical products	0	34	34
Metallic products	8	296	304
Machinery and mechanical equipment	11	521	532
Office machinery and computer equipment	0	17	17
Machinery and electrical material	5	181	186
Electronic components	2	43	45
Radio, TV, and communication equipment	5	74	79
Medical and precision instruments, optical	12	165	177
Motor vehicles	4	116	120
Shipbuilding industry	1	21	22
Aeronautical and space industry	1	9	10
Other transport material	1	21	22
Furniture	4	102	106
Games and toys	0	9	9
Other manufactories	1	39	40
Recycling	3	21	24
Electricity, gas and water supply	3	20	23
Building	4	101	105
Sale and repair of motor vehicles	1	18	19
Wholesale	6	199	205
Retail	2	32	34
Hotel and catering trade	1	6	7
Transport	0	17	17
Activities related to transport, travel agencies	0	21	21
Post and mail	0	3	3
Telecommunication services	7	27	34
Financial intermediation	1	43	44
Real estate agency	1	18	19
Machinery and equipment hiring	0	10	10
Software	40	335	375
Other computer activities	14	100	114
Research and Development	50	171	221
Architecture and engineering technical services	27	228	255
Technical analysis and trials	10	66	76
Other business activities	11	152	163
Education	0	5	5
Cinematography and video activities	1	11	12
Radio and TV activities	1	5	6
Other health, social and collective activities	8	89	97
Total	306	5118	5424

where innovation performance in a given period depends on innovation performance in the previous period and the initial values of innovation performance. The initial specification of the equation for the latent dependent variable is as follows:-

$$y_{it}^* = \alpha y_{it-1} + x'_{it}\beta + \eta_i + \varepsilon_{it} \quad (1)$$

where  $y_{it}^*$  is latent index,  $y_{it-1}$  is the first lag of innovation performance,  $x'_{it}$  is the vector of our strictly exogenous variables,  $\eta_i$  is the unobserved individual effect and  $\varepsilon_{it}$  is the error term. Since innovation performance is censored at zero:

$$y_{it} = y_{it}^* \text{ if } y_{it}^* > 0 \quad (2)$$

$$y_{it} = 0 \text{ if } y_{it}^* \leq 0 \quad (3)$$

We will use Wooldridge's (J.M. 2005) approach to estimate this model. This approach consists of defining the conditional expectation of unobserved effects through a linear function of the initial conditions and exogenous variables. Thus, it is proposed to specify the functional form of unobserved heterogeneity as density ( $\eta_i \mid y_{i0}, x_{i0}$ ):

$$\eta_i = \xi_0 + \xi_1 y_{i0} + \xi_2 x'_{i0} + \mu_i \quad (4)$$

The main advantage of this new specification is that the new unobserved individual effect  $\mu_i$  is not correlated with the initial value  $y_{i0}$ . Substituting this expression (4) in the initial specification (1) we obtain the following model:

$$y_{it}^* = \alpha y_{it-1} + x'_{it}\beta + \xi_0 + \xi_1 y_{i0} + \xi_2 x'_{i0} + \mu_i + \varepsilon_{it} \quad (5)$$

Traditionally, papers studying a similar phenomenon with similar databases have included in the specification of model (5) the within-means of the time-varying explanatory variables (e.g. Triguero and Corcoles, 2013; Garcia-Quevedo et al., 2014). However, Rabe-Hesketh and Skrondal (2013) show that the use of within-means of the time-varying explanatory variables may produce biased estimations. To address this bias, they propose including the initial-period explanatory variables in the model. We will adopt their adaptation of the Wooldridge model by including in our model the within-means of time-dependent exogenous variables excluding from the calculation of these means the initial values of the independent variables. This approach has already been used to explain innovation activities of the firms (Busom et al., 2017; Garcia-Quevedo et al., 2018).

The results of the random effects Tobit regressions can be found in Table 7. First, we estimate Model I, which contains the static Tobit estimation. Model II contains the static Tobit model with the interactions terms of our variables of interest: R&D intensity, Breadth, R&D Subsidies and Start-up. Model III shows the results of the estimation of dynamic Tobit and model IV shows the dynamic Tobit with the interaction terms.

We will focus the discussion on the results of dynamic Tobit estimations in models III and IV since these models allow us to control for initial condition and for the role of unobserved heterogeneity. The results of the dynamic Tobit show a positive relationship between R&D intensity and performance. However, the significant and negative coefficient of the interaction term between R&D intensity and start-up confirms that start-ups are less efficient in translating R&D investments into sales of innovative products. This result confirms our first hypothesis and the role of the newness liability versus smallness, since older small firms tap the R&D economic resources better than start-ups. Regarding cooperation breadth, the results also confirm for all our models our second hypothesis and the fact that start-ups will benefit to a greater extent from diverse sources of external knowledge compared to older small firms since there is a significant and positive coefficient of the interaction term between cooperation breadth and start-up. Note, those findings also confirm the curvilinear relationship found in former research (Laursen and Salter, 2006) since for all the models the parameter for cooperation breadth is significant and positive, while the parameter for its squared term is significant and negative. In Hypothesis 3, we raised the question whether R&D subsidies' effect on innovation performance

**Table 6**  
Correlation coefficients of major variables used in the model.

	Inn. perform	R&D intensity	Coop. breadth	R&D subsidies	Start-up	Size	Group	Scope	Formal appr. strat.	High-tech
R&D intensity	0.103									
<i>p</i> -value	0.000									
Coop. breadth	0.113	0.204								
<i>p</i> -value	0.000	0.000								
R&D subsidies	0.078	0.152	0.265							
<i>p</i> -value	0.000	0.000	0.000							
Start-up	0.088	0.198	0.099	0.126						
<i>p</i> -value	0.000	0.000	0.000	0.000						
Size	-0.062	-0.126	0.067	-0.074	-0.139					
<i>p</i> -value	0.000	0.000	0.000	0.000	0.000					
Group	-0.030	-0.003	0.071	-0.057	-0.023	0.379				
<i>p</i> -value	0.000	0.526	0.000	0.000	0.000	0.000				
Scope	0.003	-0.095	0.023	-0.073	-0.148	0.187	0.109			
<i>p</i> -value	0.599	0.000	0.000	0.000	0.000	0.833	0.000			
Formal appr. Strat.	0.128	0.059	0.137	0.033	0.046	0.062	-0.001	0.130		
<i>p</i> -value	0.000	0.000	0.000	0.000	0.000	0.000	0.833	0.000		
High-tech	0.118	0.250	0.145	0.173	0.166	-0.154	-0.076	-0.197	0.031	
<i>p</i> -value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
Process innov.	0.034	-0.072	0.098	-0.046	-0.044	0.128	0.045	0.042	0.065	-0.088
<i>p</i> -value	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: This table omits the correlation coefficients of year dummies.

is lower in new small firms than in SMEs. The results show a positive relationship between R&D subsidies and innovation performance. However, this result is statistically significant only for Model IV, but not for Model III. Moreover, we do not find any statistically significant difference between innovative start-ups and older SMEs, even if we observe that the sign of this interaction is negative, suggesting that SMEs tap the R&D public resources better than start-ups. Regarding the control variables, we find evidence in all models of the positive impact of the formal appropriation strategy, belonging to high-tech industries and process innovation on the innovation performance.

#### 4.2. Sensitivity analysis to further investigate the hypotheses

In order to further analyze and better understand our results, we consider that past research suggests the relevance of technological regimes for innovation (Breschi et al., 2000). The empirical research provides contradictory evidence, reflecting how different industries with different underlying knowledge contexts play a role in the relationship between R&D investments and performance of new ventures (Audretsch and Keilbach, 2007; Braunerhjelm et al., 2018). Though we controlled for it in our regressions, having observed the significant impact of firms operating in high-tech sectors, and the amount of R&D intensity for start-ups, we have conducted a sensitivity test, splitting our sample in two sub-samples according to the technology. This analysis would control for the fact that inherent sectorial conditions may drive different behaviours in start-ups and SMEs.

Results of the sensitivity test can be found in Table 8. The main result from the sensitivity analysis is that our first and second hypotheses are confirmed only for firms in high-tech sectors, while the third hypothesis is still not confirmed in any of the subsamples. The findings confirm the important role played by the knowledge intensity of the industry in explaining the relationship between newness and smallness liabilities and innovation performance.

#### 4.3. Robustness checks

We ran several further robustness checks (see appendix). First, we confirmed that the dynamic Tobit random effect models are robust to

alternative estimations. We ran random effect OLS regressions, and they confirmed Hypothesis 1 and 2. We also ran a pooled Tobit regression and we found strong evidence for Hypothesis 1 and 2. We also ran cross-sectional OLS regressions, and the estimations support Hypothesis 1 and 2.

Second, we considered alternative measures for our independent variables. For example, several scholars measure R&D intensity considering R&D expenses divided by sales (e.g. Leeuw et al., 2014). Considering this alternative measure, Hypothesis 1 is confirmed. Moreover, our measure for external innovation was based on the number of external sources of cooperation. To check that the effect of external innovation is based on the diversity of external knowledge sources rather than on monetary terms, we have created a variable that measures the percentage of external expenses related to sales, and we have re-estimated the model. In this case, Hypothesis 2 is not confirmed, neither for firms operating in high-tech sectors nor for those in low-tech sectors. Furthermore, since numerous papers measure the R&D subsidies as a dummy variable (see Cerulli, 2010), we re-estimated our regressions considering it, but Hypothesis 3 is not supported yet.

## 5. Discussion

This paper contributes to the literature on entrepreneurship since it investigates the context in which innovative start-ups are in a better position to enhance their innovation performance. As shown in the results show that the liability of newness and the liability of smallness have clearly different impacts on firms' innovation performance. The results confirm Hypotheses 1 and 2, related to the weaker contribution of R&D investments to innovation performance in start-ups compared to older small firms and the stronger contribution of a wider range of knowledge partners to innovation performance in start-ups, while rejecting Hypotheses 3, related to the weaker contribution of R&D Subsidies investments to innovation performance in start-ups.

Grounded in the spillover theory of entrepreneurship (Acs et al., 2013; Audretsch and Keilbach, 2007), our results suggest that external knowledge sourcing is more important for start-ups than monetary investment. This result confirms previous research in that firms at the beginning of their life benefit more from knowledge acquisition than from R&D resources (Kotha et al., 2011). The conundrum then is that

**Table 7**  
Estimation results.

	Static Tobit	Static Tobit with Interactions	Dynamic Tobit	Dynamic Tobit with Interactions
	Model I	Model II	Model III	Model IV
Lag Innovation Performance			0.5822*** (0.0117)	0.5820***(0.0117)
Innovation Performance t=0			0.5016*** (0.0173)	0.5007***(0.0173)
Size	-0.046 (0.0302)	-0.046 (0.0302)	0.1369** (0.0574)	0.1289** (0.0574)
Group	-0.067 (0.0571)	-0.068 (0.0571)	-0.071(0.0479)	-0.072 (0.0478)
Scope	0.2218*** (0.0256)	0.2214*** (0.0256)	0.0140(0.0328)	0.0141(0.0328)
Process Inn.	0.4414*** (0.0410)	0.4406*** (0.0410)	0.3405*** (0.0438)	0.3399*** (0.0438)
Appropriability Strategy	0.3879*** (0.0224)	0.3871*** (0.0224)	0.3119*** (0.0206)	0.3119*** (0.0206)
High-Tech	0.4757*** (0.0610)	0.4712*** (0.0610)	0.2305*** (0.0516)	0.2260*** (0.0516)
R&D Intensity	0.5669*** (0.0558)	0.6420*** (0.0596)	0.3295*** (0.0594)	0.3662*** (0.0612)
Breadth	0.4797*** (0.0344)	0.4670*** (0.0347)	0.3566*** (0.0344)	0.3488*** (0.0346)
Breadth <sup>2</sup>	-0.058*** (0.0130)	-0.060*** (0.0130)	-0.048*** (0.0121)	-0.050*** (0.0121)
R&D Subsidies	0.0334** (0.0148)	0.0413*** (0.0154)	0.0208 (0.0156)	0.0260*** (0.0161)
R&D Intensity*Start-up		-0.617*** (0.1629)		-0.357** (0.1479)
Breadth*Start-up		0.1452*** (0.0472)		0.1015** (0.0433)
R&D Subsidies*Start-up		-0.006** (0.0029)		-0.004 (0.0028)
Start-up	0.2867* (0.1642)	0.3382* (0.1863)	-0.117 (0.1178)	-0.098 (0.1452)
Year	YES	YES	YES	YES
Average Scope			0.2372*** (0.0428)	0.2361*** (0.0428)
Average Size			-0.169*** (0.0620)	-0.159** (0.0621)
Average R&D Intensity			-0.018 (0.0406)	-0.013 (0.0410)
Average Process Inn.			-0.146* (0.0828)	-0.144* (0.0828)
Average Breadth			0.0302 (0.0400)	0.0282 (0.0400)
Average R&D Subsidy			0.0144 (0.0332)	0.0152 (0.0332)
Constant	-2.000*** (0.1345)	-1.975*** (0.1345)	-2.306*** (0.1335)	-2.299*** (0.1334)
sigma_u	2.3376*** (0.0356)	2.3326*** (0.0355)	1.3899*** (0.0303)	1.3879*** (0.0303)
sigma_e	2.2301*** (0.0147)	2.2296*** (0.0147)	2.1490*** (0.0146)	2.1488*** (0.0146)
rho	0.523 (0.0079)	0.522 (0.0079)	0.2949 (0.0096)	0.2943 (0.0096)
Wald Chi2 (0.000)	1579.45	1604.79	6353.85	6368.91
Log Likelihood	-49,610.4	-49,597.666	-45,002.96	-44,997.236
Observations	37,655	37,655	35,577	35,577
Firms	5424	5424	4729	4729

Note: Standard errors in brackets. \* p < 0.10; \*\* p < 0.05; \*\*\* p < 0.01

the lack of knowledge of start-ups due to their newness may lead to a less efficient use of R&D resources. This result suggests that new ventures pose a particular challenge in terms of building up an internal knowledge base for innovation through R&D investments.

This paper also advances in the integration of open innovation with the entrepreneurship literature. Open innovation scholars have underlined the important role of external actors for the start-ups' innovation processes and have stated that future studies need to focus on them (Eftekhari and Bogers, 2015; Bogers et al., 2017). This paper found a higher effect of cooperation breadth for start-ups, leading to the comprehension of the nature of cooperation relationships. The flexibility and dynamism of the firm is key to integrate and exploit that heterogeneous external knowledge (Audretsch and Keilbach, 2007; Gimenez-Fernandez and Beukel, 2017). It leads to the conclusion that it is more important to use external knowledge than to have an extensive knowledge base as proposed by the absorptive capacity theory (Cohen and Levinthal, 1990), although the question of whether internal and external knowledge are substitutes or complements remains (Cassiman and Veugelers, 2006). However, our results may suggest that the complementarity may be just a question of time. In line with the open innovation framework, when a firm is beginning, external knowledge may be used as part of a process to build up an internal innovation capability and ultimately link this to the business model (Sandulli and Chesbrough, 2009; Chesbrough and Bogers, 2014; West and Bogers, 2014).

In this study, we aimed to investigate external innovation orientation in terms of diverse sources of external knowledge rather than investment. In line with the theory of knowledge spillover entrepreneurship, establishing multiple connections is crucial for firms operating in high-tech sectors, as we revealed in our sensitivity tests, suggesting that knowledge-driven business opportunities are linked to environments rich in knowledge (Audretsch and Keilbach, 2007). The results confirm former entrepreneurship research in that start-ups in order to overcome the newness liability follow a collaborative entrepreneurial strategy, which allow them to overcome their limitations while they explore and exploit business opportunities (Burgelman and Hitt, 2007). The also benefit more from knowledge exploitation when engaging in a diversity of cooperation activities because partners offer complementary assets (Colombo et al., 2006; Ketchen et al., 2007). Results can be understood from an organizational learning perspective, since start-ups benefit more from knowledge exploration when engaging in a diversity of cooperation activities because they need to access more knowledge and learn from their partners (Autio et al., 2000; Pangarkar and Wu, 2013).

Given that our hypotheses are only supported in high-tech settings, it may imply that high-tech start-ups are to some extent "born open" in that their business model design process requires a continuous iteration based on external stakeholder involvement (Saravathy, 2001; Blank, 2013). This result also confirms that entrepreneurial activity does not exist in a vacuum, it is dependent on external sources (Audretsch and Keilbach, 2007; Lerner, 2010; Acs et al., 2013) and

**Table 8**  
Estimation Results. Sub-samples high-tech and non-high-tech sectors.

	High Tech Static Tobit with Interactions Model V	High Tech Dynamic Tobit with Interactions Model VI	Non-High Tech Static Tobit with Interactions Model VIII	Non-High Tech Dynamic Tobit with Interactions Model VIII
Lag Innovation Performance	0.5106*** (0.0151)	0.6961*** (0.0196)		
Innovation Performance t=0	0.4936*** (0.0212)	0.4785*** (0.0263)		
Size	0.0147 (0.0387)	0.1722** (0.0712)	-0.103** (0.0459)	0.1184 (0.1027)
Group	-0.207*** (0.0748)	-0.175*** (0.0635)	0.0496 (0.0882)	0.0060 (0.0709)
Scope	0.1271*** (0.0334)	-0.019 (0.0415)	0.2872*** (0.0394)	0.0514 (0.0553)
Process Inn.	0.4647*** (0.0522)	0.3272*** (0.0560)	0.4626*** (0.0665)	0.3575*** (0.0717)
Appropriability Strategy	0.3424*** (0.0292)	0.2747*** (0.0271)	0.4619*** (0.0353)	0.3795*** (0.0317)
R&D Intensity	0.6397*** (0.0738)	0.3871*** (0.0780)	0.6428*** (0.0999)	0.3868*** (0.0998)
Breadth	0.3939*** (0.0453)	0.3296*** (0.0451)	0.5583*** (0.0542)	0.3373*** (0.0547)
Breadth <sup>2</sup>	-0.049*** (0.0162)	-0.045*** (0.0151)	-0.076*** (0.0221)	-0.049** (0.0206)
R&D Subsidies	0.0692*** (0.0200)	0.0527** (0.0211)	0.0089 (0.0242)	0.0020 (0.0253)
R&D Intensity* Start-up	-0.630*** (0.1904)	-0.363** (0.1731)	-0.423 (0.3017)	-0.322 (0.2771)
Breadth* Start-up	0.2016*** (0.0531)	0.1473*** (0.0493)	0.0421 (0.0971)	0.0326 (0.0843)
R&D Subsidies* Start-up	-0.007** (0.0035)	-0.004 (0.0033)	-0.005 (0.0057)	-0.006 (0.0054)
Start-up	0.2549 (0.2186)	-0.146 (0.1751)	0.7173** (0.3043)	0.1390 (0.2343)
Year	YES	YES	YES	YES
Average Scope		0.2167*** (0.0565)	0.1797*** (0.0661)	
Average Size		-0.213*** (0.0775)	-0.117 (0.1086)	
Average R&D Intensity		-0.017 (0.0475)	0.0090 (0.0772)	
Average Process Inn.		-0.023 (0.1050)	-0.182 (0.1280)	
Average Breadth		-0.009 (0.0501)	0.1238** (0.0619)	
Average R&D Subsidy		-0.0001 (0.0418)	0.0239 (0.0497)	
Constant	-1.251*** (0.1599)	-1.724*** (0.1638)	-2.429*** (0.2049)	-2.728*** (0.1923)
sigma_u	2.2459*** (0.0445)	1.3639*** (0.0384)	2.4872*** (0.0550)	1.3880*** (0.0486)
sigma_e	2.1608*** (0.0186)	2.0936*** (0.0186)	2.2572*** (0.0236)	2.2053*** (0.024)
rho	0.5193 (0.0103)	0.2979 (0.0125)	0.548 (0.0115)	0.283 (0.0153)
Wald Chi2 (0.000)	854.79	3347.25	698.37	2949.34
Log Likelihood	-28,127.615	-25,561.911	-21,460.651	-19,408.294
Observations	19,923	18,799	17,732	16,778
Firms	2966	2626	2458	2103

Note: Standard errors in brackets. \* p < 0.10; \*\* p < 0.05; \*\*\* p < 0.01

**Table 9**  
Summary of hypotheses testing results.

Hypothesis	Description	Relationship	Proposed Relationship	Result	Conclusion
H1	Compared to older innovative small firms, the effectiveness of R&D investments will be lower in innovative small start-ups.	The contribution of <i>R&amp;D Intensity</i> variable to innovation performance is moderated by <i>Start-up variable</i> .	Negative Interaction Term	Supported	R&D investments have a <u>weaker</u> contribution to innovation performance in small start-ups compared to older small firms.
H2	Compared to older innovative small firms, the innovative effectiveness of broader range of external knowledge sourcing will be higher in innovative small start-ups.	The contribution of <i>Breadth</i> variable to innovation performance is moderated by <i>Start-up variable</i> .	Positive Interaction Term	Supported	A broader range of external knowledge sources makes a <u>stronger</u> contribution to innovation performance in small start-ups compared to older small firms.
H3	Compared to older innovative small firms, the innovative effectiveness of R&D subsidies will be lower in small innovative start-ups.	The contribution of <i>R&amp;D Subsidies</i> variable to innovation performance is moderated by <i>Start-up variable</i> .	Negative Interaction Term	Not Supported	In small firms, the contribution of R&D Subsidies to innovation performance does <u>not depend</u> on the age of the firm.

leaves open the question as to whether the theory of knowledge spillover entrepreneurship would explain entrepreneurship only in knowledge intensive and more turbulent environments like high-tech industries. This dynamism of small start-ups to integrate external knowledge is in line with the extension of absorptive capacity developed by the knowledge spillover theory of entrepreneurship, which introduced the concept of entrepreneurial absorptive capacity (Qian and Acs, 2013). Entrepreneurial absorptive capacity is defined as the abil-

ity of entrepreneurs to understand new knowledge, recognize its value, and commercialize it (Qian and Acs, 2013). It is not therefore based on the extension of the knowledge base, but on the capacity to utilize external knowledge. The importance of cooperation built through diverse external sources is reinforced by the robustness check where we measured external R&D in monetary terms, which did not yield any significant result even for firms operating in high-tech sectors. Hence, the study confirms former research in that the diversity of external knowl-

edge sources is more important for innovation performance than the amount of financial resources devoted to obtain those external resources (Colombo et al., 2006).

Moreover, we proposed that the impact of R&D subsidies on innovation performance is lower for start-ups. Although we did not find support for this hypothesis, the robustness check results suggest that R&D subsidies have lower impact for start-ups, and we can at least argue that there are no clear differential effects of R&D subsidies between new ventures and SMEs, making any such claim more ambiguous. Scholars have generally argued about the effectiveness of public intervention on the economy (Autio et al., 2014), providing a mixture of results and justifications. Literature on the effect of public subsidies for start-ups is more scant and as discussed above is quite critical with respect to the role of direct R&D subsidies on their performance (Lerner, 2010). R&D subsidies might influence innovation performance since they can moderate financial bottlenecks for the firm's R&D activities, but firms must employ that funding appropriately. A Spanish study by Alonso-Nuez and Galve-Górriz (2012) found similar results to our research, since they could neither support nor reject the arguments for or against the effectiveness of public programs. There was no difference between subsidized companies and unsubsidized companies regarding the survival expectancy or net profits. Existing evidence supports our two last hypotheses since R&D subsidies may not have a positive direct impact on the innovative performance of small new ventures, but they can be employed as a signal of firms' innovative capabilities and put new ventures in a better position to enter cooperation relationships (Autio et al., 2008; Meuleman and De Maeseneire, 2012).

From a managerial perspective, this study highlights which is the best strategy to follow for innovative start-ups. Since start-ups would lack managerial attention to push several strategies at the same time, they should focus on one that yields the maximum benefits. While cooperation breadth is important for all firms, their positive effects are increased if the firm is a start-up operating in knowledge-intensive sectors. Investing in R&D would not generate a competitive advantage related to incumbent firms in knowledge intensive industries. From a policy perspective, governments might provide support during the initial difficulties of start-ups to prevent their high failure rate. There are plenty of ways in which governments can intervene in the entrepreneurial sector, for example through public funding for venture investors, subsidies, educational programs, creating networks of firms, but not all of them are equally effective. As we show in this study, start-ups gain more advantage from cooperative relationships, so policies should therefore design programs that support start-ups in the creation of networks. This is a relevant finding, since some policy instruments such as the European Commission's SME Instrument seems to go in the opposite direction, financially supporting the isolated R&D activity of start-ups, rather than promoting their participation in international networks. Moreover, large and R&D-intensive firms are currently those that benefit most from public policies that provide incentives for cooperation, with small start-ups often forgotten in this type of programs (Barge-Gil, 2010). The literature suggests several possible instruments to enhance start-ups' social capital, such as public incubators (Frenkel et al., 2008), easier participation of start-ups in equity markets (Shan et al., 1994) and public support for the creation and consolidation of professional associations in emerging knowledge fields (Landry et al., 2002).

## 6. Conclusion

Small innovative start-ups are the motor of the economy for many countries. Policy measures focused on start-ups' relationships would thus subsequently improve the innovation outcomes of the country. The aim of this study was to isolate the impact of newness liability from smallness liability on innovation performance in order to deter-

mine whether an internal or external focus is better for small innovative start-ups. Existing research does not make fully clear which resources are better when providing support to small start-ups: Will stronger internal R&D resources help address smallness liabilities, or will easier access to external resources help mitigate the liability of newness and reinforce organizational learning? According to the theory of knowledge spillover entrepreneurship, we confirm that start-ups are able to convert external knowledge into societal utility. This paper seeks an understanding of an entrepreneurship policy that stimulates the innovative endeavours of new firms. In particular, we examined the role of R&D intensity, external connections, and R&D subsidies as strategies that could boost or be detrimental to start-ups' innovation performance. Based on our discussion, we posit the question about which resources are better when supporting new firms. Our results suggested that from a public policy point of view, start-ups will benefit more from policy instruments that support external knowledge orientation rather than focusing on the development of internal R&D.

This study has several limitations that could be overcome with follow-on studies. First, the main goal of the study was to compare innovative start-ups with innovative older firms since the most important policy instruments focus on innovative firms. However, further research would be needed to analyze newness and smallness in non-innovative firms. Second, this study suggests the effectiveness of different policy measures for start-ups according to the strategies that could generate a competitive advantage for these firms. However, we did not directly measure different institutional contexts such as the technological regime where the start-up competes. Future studies could include not only firm level factors, but also external context factors to determine the innovation pattern of these firms. Third, we found a significant contribution of process innovation; however, our measure of process innovation may not grasp its complexities and its links to product innovation. Fourth, it would be desirable to use sampling frames other than Spanish firms to extend the validity of the findings. The positive effects that start-ups benefit from when cooperating with a diversity of partners could be higher in first-runners and technologically advanced countries, but it could disappear in those based on the imitation of technologies. Finally, another caveat is the age of our dataset. Readers should be warned that the context in which start-ups and small firms operate could be slightly different.

More generally, this study also leaves some interesting issues for future research. We analysed the role of start-ups as a contingent factor, but it would be interesting to focus exclusively on them. In particular, we showed the positive effect of cooperation breadth on innovation performance for start-ups, but its effect could be dependent on the type of alliance. A diversity of external source relationships can be used as a key tool for innovation. Future research should however still investigate the specific limitations of external knowledge sourcing in new ventures and how different sources may play a particular role (cf. Laursen and Salter, 2006). At the same time, our findings could be linked to the "human side" of such openness and the role of the individual entrepreneur or entrepreneurial team in this context (Baron and Tang, 2011; Gruber et al., 2013). Moreover, start-ups' benefits could depend on the geography of the cooperation. An international entrepreneurship perspective would help to understand the knowledge network spread of a firm and its evolution.

## CRedit authorship contribution statement

**Elena M. Giménez-Fernández:** Conceptualization, Methodology, Writing - original draft, Investigation, Data curation, Writing - review & editing, Visualization. **Francesco D. Sandulli:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Investigation, Writing - review & editing, Supervision, Project administration, Funding acquisition. **Marcel Bogers:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

**Table A.1**  
Estimation results of robustness checks.

	OLS, random effects Model I	Pooled Tobit Model II	Pooled OLS Model III	Alternative measures static Tobit Model IV	Alternative measures, dynamic Tobit Model V
Lag Innovation Performance					0.593***[0.018]
Innovation Performance t=0					0.507***[0.012]
Size	-0.030** [0.012]	-0.081*** [0.020]	-0.048*** [0.009]	0.002 [0.033]	0.140** [0.061]
Group	-0.043* [0.024]	-0.107*** [0.041]	-0.064*** [0.018]	-0.005 [0.061]	-0.031 [0.050]
Scope	0.087*** [0.010]	0.298*** [0.020]	0.109*** [0.008]	0.247*** [0.028]	0.016 [0.035]
Appropriability Strategy	0.192*** [0.010]	0.640*** [0.021]	0.284*** [0.010]	0.399*** [0.024]	0.345*** [0.021]
High-Tech	0.225*** [0.025]	0.524*** [0.044]	0.252*** [0.020]	0.399*** [0.066]	0.183*** [0.054]
Process Inn.	0.190*** [0.018]	0.495*** [0.040]	0.220*** [0.017]	0.463*** [0.044]	0.343*** [0.040]
R&D Intensity	0.356*** [0.026]	0.964*** [0.051]	0.485*** [0.023]	0.478*** [0.032]	0.329*** [0.028]
Breadth	0.196*** [0.016]	0.516*** [0.034]	0.194*** [0.015]	0.650** [0.254]	0.615** [0.235]
Breadth^2	-0.019*** [0.006]	-0.089*** [0.013]	-0.023*** [0.006]	-0.241*** [0.080]	-0.221*** [0.075]
R&D Subsidies	0.017** [0.007]	0.015 [0.016]	0.007 [0.007]	0.147*** [0.049]	0.131*** [0.045]
Start-up	0.170** [0.066]	0.280*** [0.102]	0.162*** [0.045]	0.555*** [0.204]	0.096 [0.156]
R&D Intensity*Start-up	-0.327*** [0.071]	-1.100*** [0.135]	-0.502*** [0.060]	-0.272*** [0.090]	-0.185** [0.078]
Breadth*Start-up	0.120*** [0.034]	0.172** [0.067]	0.097*** [0.031]	0.035 [0.286]	0.279 [0.262]
R&D Subsidies*Start-up	-0.03 [0.024]	-0.063 [0.053]	-0.02 [0.023]	-0.071 [0.186]	-0.147 [0.171]
Year	YES	YES	YES	YES	YES
Average Scope					0.256***(0.045)
Average Size					-0.099(0.066)
Average R&D Intensity					-0.594343** (0.253)
Average Breadth					29.121** (13.299)
	0.602*** [0.052]	-2.013*** [0.098]	0.579*** [0.042]	-2.505*** [0.148]	-4.206*** [0.448]
sigma_u	0.830			2.378*** [0.038]	1.378*** [0.031]
sigma_e	1.235			2.237*** [0.016]	2.197*** [0.016]
rho	0.311			0.531 [0.008]	0.282 [0.009]
Sigma		3.044 [0.020]			
Log Likelihood		-5.39E+04	-6.95E+04	-4.39E+04	-41,659
No of Obs	37,655	37,655	37,655	33,650	33,319
F			172.86***		
R-squared			0.0956		
LR/Wald-Chi2	2015.439***	3727.36***		1211.951***	5733.55***

Note: Standard errors in brackets. \* p < 0.10; \*\* p < 0.05; \*\*\* p < 0.01

## Declaration of Competing Interest

None.

## Appendix A

Table A.1

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