Technological Environment and Technology Entrepreneurship: A Cross-Country Analysis

Ana Colovic and Olivier Lamotte

Recent years have seen growing interest in the influence of the environment on entrepreneurship. However, little is known about the impact of the country-level technological environment on the creation of new technology-based firms. This study investigates the relationship between the technological environment (measured by the amount of investment in R&D, and access to information and communication technology [ICT] infrastructure) and technology entrepreneurship, in 54 countries during the years 2005 to 2010. Using data from the Global Entrepreneurship Monitor, and the World Bank Development Indicators, we identify a significant, robust inverted U-shaped relationship between R&D investment at country level and the likelihood of technology entrepreneurship. We also find evidence of a positive relationship between access to ICT infrastructure and the likelihood of technology entrepreneurship.

Introduction

In recent years, there has been growing agreement among scholars and practitioners that so-called 'high-impact entrepreneurs' (Acs, 2010), defined as entrepreneurs who are inclined to pursue innovation and growth, contribute significantly to the economic growth and prosperity of nations (Shane, 2009; Stenholm, Acs & Wuebker, 2013; Brown & Mason, 2014; Ratinho, Harms & Walsh, 2015) and respond to the major challenges of today's world (Thukral et al., 2008; Groen & Walsh, 2013). However, according to Minniti and Lévesque (2010), the numbers of high-impact entrepreneurial firms (i.e., technology-based new ventures) vary greatly from country to country. Although such variations have traditionally been explained by inherent factors related to the entrepreneurs themselves, several recent studies suggest that research should examine more carefully the context in which entrepreneurial firms proliferate (Shane & Venkataraman, 2003; Stuart & Sorenson, 2003; Minniti & Lévesque, 2008; Acs, Audretsch & Lehmann, 2013). The reason for this is that the ability of an entrepreneur to perceive an innovative business idea depends not only on individual factors such as creativity (Audretsch & Belitski, 2013), but also on the efforts of different actors to whom entrepreneurs are connected (Garud & Karnoe, 2003) and on the surrounding environment (Koellinger, 2008; Acs, Audretsch & Lehmann, 2013; Laplume, Pathak & Xavier-Oliveira, 2014; Thai & Turkina, 2014). As argued by Acs, Autio and Szerb (2014, p. 477), 'National systems of entrepreneurship cannot be properly understood without considering both population-level processes (attitudes, ability and aspirations) and the institutional context within which these processes are embedded'.

Previous research has focused on understanding variations in new firm creation across countries (Wennekers, Uhlaner & Thurik, 2002; Acs, Autio & Szerb, 2014) and in particular it has aimed at analysing the impact of different conditions (political, economic, legal, technological, cultural and demographic) on entrepreneurial activity (Wennekers, Uhlaner & Thurik, 2002; Acs, Desai & Hessels, 2008; Aidis, Estrin & Mickiewicz, 2008, 2012; El Harbi & Anderson, 2010; Fink, Lang & Harms, 2013; Hayton & Cacciotti, 2013; Stenholm, Acs & Wuebker, 2013; Acs, Autio & Szerb, 2014). However, empirical studies on the contextual determinants of entrepreneurship have led

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to different conclusions and to contrasting directions in the influence of different factors (Thai & Turkina, 2014). Thus, there has been evidence of the positive influence on entrepreneurship of factors such as institutions and technology advancement (Kaufmann, Kraay & Mastruzzi, 2006; Nyström, 2008; Harms, Wdowiak & Schwarz, 2010), but also of the negative influence of the same factors (Naudé, 2009), or a U-shaped relationship between these environmental conditions and entrepreneurship (Wennekers et al., 2005).

However, despite a growing body of literature on the environmental determinants of entrepreneurship, little is known about the ways the technological environment at national level impacts the likelihood of technology entrepreneurship, which can be defined as the creation of new firms that develop or use new technologies. Technology entrepreneurship is therefore different from mainstream entrepreneurship insofar as it focuses on new opportunities through innovation in science and engineering (Shane & Venkataraman, 2003; Beckman et al., 2012).

In this research, we analyse the relationship between the technological environment, which we measure by R&D investment at the country level, and access to information and communication technology (ICT) infrastructure, and the likelihood that an entrepreneur will become involved in technology entrepreneurship. Combining contrasting insights from previous research, we hypothesize that the relationship between R&D investment at the country level and the likelihood of technology entrepreneurship is positive, but only up to a certain point, after which it becomes negative. It therefore has an inverted U-shape. We also hypothesize that access to ICT infrastructure positively influences the likelihood of technology entrepreneurship. To test the relationship between the technological environment and the likelihood of technology-based new venture creation empirically, we use the Global Entrepreneurship Monitor (GEM) database and technology indicators drawn from World Bank data for 54 countries for the years 2005 to 2010. Consistent with previous studies, we control for both the characteristics of entrepreneurs and the economic development of these countries.

Our study contributes to research into the effects of the environment on entrepreneurial activity in three ways. First, it provides insights into the environmental determinants of a crucial phenomenon, the creation of technology-based firms. Although there is a vast literature on the inherent and contextual determinants of new firm creation in general, technology-based firms exhibit several features that require specific investigation. Second, our study focuses on the country-level rather than industry-level technological environment, which distinguishes our research from the bulk of studies focusing on industry-level determinants of new firm creation (Dean & Meyer, 1996). Finally, our work is based on a large-scale, cross-country analysis that covers a variety of settings, which thus makes our findings more generalizable.

Technological Environment and Technology Entrepreneurship: Framework and Hypotheses

Previous research suggests that environmental factors strongly influence variations in entrepreneurial activity across countries (Shane & Venkataraman, 2003; Acs & Armington, 2006; Aidis, Estrin & Mickiewicz, 2008; Minniti & Lévesque, 2010; Acs, Autio & Szerb, 2014; Brown & Mason, 2014; Laplume, Pathak & Xavier-Oliveira, 2014). As suggested by Arenius and Minniti (2005, p. 243), 'the entrepreneurial environments of some countries are more conducive to entrepreneurial behaviour while others penalize it'. Wennekers, Uhlaner and Thurik (2002) identify the following five macro-level determinants of variations in the rate of entrepreneurship across countries and over time: economic development, demography, culture, institutions and technology. This research focuses on one of these macro-level determinants of entrepreneurship: technology, or more generally the technological environment, which we broadly define as scientific knowledge and technology produced and available in a country. It therefore comprises not only technology per se, but also the result of investment in innovation and R&D made both by private firms and public institutions.

New ventures, which act as 'knowledge filters' (Acs et al., 2004), are important means of bringing innovation to the market (Schumpeter, 1934; Venkataraman, 1997). These ventures usually have high growth objectives and thus require commitment from inventors and technology developers (Hindle & Yencken, 2004) in addition to being dependent on the interplay of different environmental factors. We argue that because nascent organizations that develop or use new technologies rely on the environment for resources, legitimacy and support (Townsend & Hart, 2008), traditional person-centric analyses should be complemented by studies of the technological environments in which technology-based ventures emerge (Acs, Audretsch & Lehmann, 2013).

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Organizations are embedded in country-specific technological settings (Busenitz, Gomez & Spencer, 2000). Focusing particularly on innovation and technology, the concept of national systems of innovation (NSI) (Lundvall, 1992; Nelson, 1993) identifies important dimensions that shape the innovation results of a particular country (Samara, Georgiadis & Bakouros, 2012). These are: the generation of new knowledge, the absorptive capacity or ability to exploit this knowledge, and an external environment that is not prejudicial to innovation (Lundvall, 1992). According to the NSI model, the structures in which R&D processes are embedded greatly determine the innovation productivity of nations and consequently the rate of creation of technology-based firms, although 'the core works of the NSI literature hardly even evoke the term *entrepreneurship*' (Acs, Autio & Szerb, 2014, p. 477).

Country-specific technological settings depend broadly on the institutional frameworks of the country and on the dynamics of the incumbent firms, and can be apprehended by R&D-related investment as well as the technological infrastructure of a country. Several previous studies have examined the impact of some of these features on the rate of new firm creation in general. Choi and Phan (2006) have thus found that R&D stock per capita positively influences new venture creation. According to the recent knowledge-spillover theory of entrepreneurship (Acs et al., 2009; Acs, Audretsch & Lehmann, 2013), which is concerned with the contextual variables that shape entrepreneurship, a context which is rich in knowledge generates entrepreneurial opportunities. The key hypothesis of the theory is that knowledge created by incumbent firms and research organizations spills over to other economic agents, in this case entrepreneurs. Those entrepreneurs able to absorb knowledge and convert it to economic knowledge, that is, products or services, do not need to bear the full costs of knowledge development (Acs, Audretsch & Lehmann, 2013). It is, therefore, the potential for taking advantage of a knowledge spillover that creates entrepreneurial opportunity (Acs et al., 2009).

Indeed, in current competitive environments, acquiring external knowledge and technologies in addition to undertaking in-house technological developments have become critical factors in entrepreneurship (Hussinger, 2010; Berchicci, 2013; Martin-Rojas, Garcia-Morales & Bolivar-Ramos, 2013). Consequently, researchers have argued that the higher the level of R&D activity in a country, the more knowledge is produced and the greater are the opportunities for entrepreneurs to exploit them (Acs, Audretsch & Lehmann, 2013). Audretsch, Keilbach and Lehmann (2006, p. 44) suggest that 'ceteris paribus, entrepreneurial activity will tend to be greater in [spatial] contexts where investments in new knowledge are relatively high, since the new firm will be started from knowledge that has spilled over from the source producing that new knowledge'.

Likewise, El Harbi and Anderson (2010) argue that the R&D infrastructure of a country greatly influences the nature of the enterprises that are created in that country. If a country has strong R&D infrastructure, then a potential entrepreneur can take advantage of this infrastructure to create a research-based venture. Conversely, if the R&D infrastructure of a country is underdeveloped, then entrepreneurs will not base their activity on research; rather, entrepreneurs in such a country are likely to imitate innovations from other countries. To sum up, a significant body of literature is based on the underlying hypothesis that the higher the level of R&D investment in a country, the higher should be the rate of entrepreneurship, including the creation of technology-based ventures.

However, there are also findings suggesting that the relationship between the technological environment and technology-based firm creation is not as straightforward as it may appear. Indeed, previous literature has also provided evidence of a negative relationship between R&D investment and new firm creation. One of the explanations for this finding is the role of large existing private and public research centres, which may take advantage of environments characterized by significant investment in R&D to concentrate research and technology, thus reducing the opportunities for potential entrepreneurs. This finding has been known to the academic literature for some time now, especially at industry level. Orr (1974) and Audretsch (1995) thus show that routinized technological regimes (creative accumulation), which are dominated by the innovation of large firms, represent an entry barrier for entrepreneurial ventures. Moreover, Acs et al. (2009) show that when incumbent firms appropriate all the rents from R&D through patents, there is less knowledge spillover and thus less entrepreneurial activity. This implies that even though a great quantity of knowledge is generated by incumbent firms, this knowledge does not always spill over to potential entrepreneurs because incumbents utilize all the knowledge produced by transforming it into commercial products. Moreover, as Minniti and Lévesque (2010) argue, higher R&D expenditure does

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not systematically result in greater entrepreneurship and growth because a large number of entrepreneurs, especially those in emerging countries, are imitative. These insights from prior works therefore point to the existence of a negative relationship between the level of R&D investment and entrepreneurship.

We now combine insights from prior research suggesting both a positive and a negative relationship between R&D investment and entrepreneurship to argue that the relationship between the technological environment and technology entrepreneurship is non-linear. Firstly, we posit that, in order for technology entrepreneurship to proliferate, there should be a certain level of R&D investment. In other words, we argue that it is unlikely that such entrepreneurship will develop extensively in settings in which R&D levels are very low. Secondly, in line with the knowledge spillover theory of entrepreneurship, as levels of R&D investment at the country level increase, the likelihood of technology entrepreneurship will also increase, but only up to a certain point, after which the likelihood of such entrepreneurship will decrease, because in such environments large incumbent firms appropriate the rents from innovations, technologies and patents, thus hampering external spillovers.

The distinction between Schumpeter Mark I and Mark II regimes may be relevant in explaining the nonlinear relationship between R&D investment and entrepreneurship. In the Schumpeter Mark I regime (creative destruction), new entrepreneurs challenge incumbents by introducing new inventions, whereas in the Mark II regime, the incumbents determine the rate of innovation (Carree et al., 2002). This might suggest that the likelihood of technology entrepreneurship increases with higher investment in R&D at country level, but only to a certain point, starting from which the relationship is reversed. This turning point could represent the borderline between the types of Schumpeter regimes that prevail in a country.

In line with these insights, we hypothesize that the relationship between R&D investment at country-level and the likelihood that entrepreneurs will enter technology entrepreneurship takes a curvilinear, inverted-U-shaped form:

H1: There is an inverted U-shaped relationship between country-level R&D investment and the likelihood that individuals will engage in technology entrepreneurship.

Infrastructure projects have played an important role both in fostering new firm creation (Chandler, 2006; Audretsch, 2007a, 2007b; Cumming & Johan, 2010) and in providing access to technology (Feldman & Audretsch, 1999; Venkataraman, 2004). Wennekers et al. (2010) argue that ICT has been a major driving force in the growth of entrepreneurship in recent years. In particular, the Internet facilitates the transmission of information and culture (Friedman, 2005) and stimulates the transfer of knowledge between firms (Cukor & McKnight, 2001; Feldman, 2002). Therefore, ICT is believed to foster the creation of new ventures by radically changing the relationship between entrepreneurship and innovation. Thanks to the Internet, entrepreneurs in rural and remote areas can access clients and suppliers (Cumming & Johan, 2010); thus, the use of the Internet diminishes the effects of distance. Moreover, ICT stimulates outsourcing and enables the exploitation of new ideas; it opens new horizons of opportunity (Etemad, Wilkinson & Dana, 2010) that lead to new firm start-ups (Wennekers et al., 2010).

While it might seem obvious and not particularly necessary to analyse access to ICT infrastructure in the case of developed countries, it is extremely relevant in the case of developing economies. Indeed, in these economies, many regions have no access to ICT infrastructure or access is poor (Kiss, Danis & Cavusgil, 2012). As our sample includes many of these developing countries, the inclusion of access to ICT infrastructure as a variable that grasps the technological environment is therefore critical. We argue that ICT infrastructure, which facilitates access to knowledge and business partners, can positively influence the creation of technology-based firms. Accordingly, we formulate the following hypothesis:

H2: Individuals will be more likely to engage in technology entrepreneurship in countries in which there is easy access to ICT infrastructure.

Data and Empirical Methods

The aim of this paper is to analyse the relationship between technology entrepreneurship, R&D expenditure and access to ICT in various countries during the years 2005 to 2010. In this section, we present the variables, data and econometric techniques that we used in our empirical work.

Data and Sample

We tested our hypotheses using GEM and World Bank data. GEM is currently the largest cross-country survey examining the prevalence, determinants and consequences of entrepreneurship. The GEM survey is an annual assessment of the level of

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Table 1. Definitions of the Variables and Descriptive Statistics

Variable	Variable definition	Descriptive statistics			
		Mean	SD	Min	Max
Technology entrepreneurship	= 1 if the technology or procedure that is required for the product has been available for less than 1 year, 0 otherwise	0.12	0.33	0	1
R&D expenses	Current and capital expenditure (both public and private) on creative work undertaken to increase knowledge (in % of GDP)	1.31	0.91	0.02	4.83
Broadband	Number of broadband subscribers with a digital subscriber line, cable modem or other high-speed technology (per 100 people)	11.75	10.46	0.02	23.40
Age	Age of the individual in years at the time of the survey	38.05	11.95	15	99
Male	= 1 if the individual is male; 0 otherwise	0.58	0.49	0	1
Post-secondary education	= 1 if the individual has attained a post-secondary or higher education level; 0 otherwise	0.38	0.48	0	1
Opportunity	= 1 if the individual reports an opportunity (vs. necessity) motive for entrepreneurship; 0 otherwise	0.70	0.46	0	1
Technology sector	= 1 if the entrepreneurial activity occurs in the medium- or high-technology sector; 0 otherwise	0.04	0.20	0	1

entrepreneurial activity within and between countries. Except for the last four years, GEM data is publicly available. GEM data are derived from representative samples of surveys of at least 2000 randomly selected adults per country, including both entrepreneurs and non-entrepreneurs (for details on the data collection, see Reynolds et al., 2005; for the GEM model, see Levie & Autio, 2008). Our empirical study is therefore based on individual-level data. For 2010, the data covered 55 developed and developing countries. The full list of countries included in the data set is available in the Appendix. Because some of the data on independent variables was missing, Taiwan was not included in the regression analysis. World Development Indicators (WDI) include the primary World Bank collection of development indicators compiled from officially recognized international sources. Detailed definitions of the variables and descriptive statistics are presented in Table 1.

Dependent Variable

Our study focuses on technology entrepreneurship and aims to understand the environmental determinants of technology venture creation among individuals engaged in entrepreneurial activity. Therefore, we consider only individuals who are engaged in entrepreneurial activity using the *Total early-stage entrepreneurial activity* (TEA) GEM subset (i.e., nascent entrepreneurs and new businesses from 3 months to 42 months old). Our total sample is made up of 68,032 individuals. Both technology and non-technology entrepreneurs are included in the sample. The variable that we are attempting to explain, *Technology entrepreneurship*, is a dichotomous variable that takes the value 1 if the technology or procedure that is required for a product or a service has been available for less than one year, 0 otherwise. Therefore, the *Technology entrepreneurship* variable identifies entrepreneurs that enter the market with a product or

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service using a new or very recent technology. Recent studies based on GEM data have used this variable to identify technology entrepreneurship (Laplume, Pathak & Xavier-Oliveira, 2014). The variable is based on the question asking entrepreneurs about the type of technology they use (less than one year old or more than one year old).

Explanatory Variables

The independent variables of interest are drawn from the WDI. As hypothesized in the previous section, the technological environment influences technology entrepreneurship through two dimensions: knowledge creation resulting from R&D expenditure by private and public organizations; and access to ICT infrastructure at country level. These two dimensions are operationalized through two variables: R&D expenditure and access to high-speed Internet. The two explanatory variables are therefore *R&D expenses* and *Broadband*. The *R&D expenses* variable measures the level of public and private expenditure on creative work undertaken in a country to increase knowledge, expressed as a percentage of GDP. R&D investment has been widely used in academic research, and its relevance in the study of innovation is well accepted (Acs et al., 2009).

To test Hypothesis 2 (i.e., the influence of access to ICT infrastructure on technology entrepreneurship), we use the *Broadband* variable, which corresponds to the number of broadband subscribers with a digital subscriber line, cable modem or other high-speed technology in the country.

Control Variables

Several individual-level control variables are drawn from the GEM dataset. Consistent with previous studies (Lévesque & Minniti, 2006; Minniti & Nardone, 2007; Aidis, Estrin & Mickiewicz, 2008), the personal characteristics of entrepreneurs, such as age, gender and education, may influence technology entrepreneurship because these characteristics affect entrepreneurial activity in general. Other GEM-based control variables include the motivation for entrepreneurship, either *Opportunity* or *Necessity* (McMullen, Bagby & Palich, 2008) and the *Technology sector* of the nascent or new activity. In particular, opportunity as a motivation is more likely to generate technology entrepreneurship, as this is believed to be consistent with Schumpeterian innovation, whereas necessity is more likely to be related to imitative entrepreneurship (McMullen, Bagby & Palich, 2008). Moreover, technology entrepreneurship is, understandably, believed to be more common in high-technology sectors. Thus, Thornhill (2006) found that in a dynamic high-technology sector, the percentage of firms that introduced national or world-first new products was more than double that in a low-technology sector. This result indicates that high-technology industries are characterized by higher rates of innovative activity. Finally, country and year dummies are also included in all regressions to control for country-level differences in terms of economic development and institutions over time. There are significant differences between the countries considered in this study, particularly because they include both developed and developing economies. Moreover, the world economic situation changed radically over the period of the survey. Consequently, it is necessary to control for sudden changes in the external environment of these countries.

Estimation Methods

The explained variable, *Technology entrepreneurship*, is a dummy variable; therefore, we use a probit model. In our empirical study, we combine individual-level variables and country-level variables because we expect the creation of new technology-based firms to be influenced by the technological environment at country level. In such a hierarchical model, individual-level observations within the same country are interdependent, which leads to biased standard errors. To address this issue, we adopt an estimation strategy that corrects for the correlation of error terms among individuals at the country level and calculates robust standard errors. More specifically, standard error terms are clustered for all observations in the same country and year. We present the correlation between the variables in Table 2. As the estimations combine individual-level outcomes with country-level variables, there is no simultaneity bias (i.e., reverse causality): the individual decisions of entrepreneurs do not affect country-level institutions (Aidis, Estrin & Mickiewicz, 2012).

Results

The results are reported in Table 3. In column (1), the estimation includes only the control variables; in columns (2)–(4), we include the explanatory variables to test H1 and H2. We first run regressions for each explanatory variable (columns 2 and 3) and then we incorporate the two explanatory variables in the same model (column 4). In accordance with Hoetker (2007), we report McFadden's and McKelvey & Zavoina's pseudo-R^2, which conform to comparable empirical studies with similar

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Table 2. Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Technology entrepreneurship	1.00							
(2) R&D expenses	–0.04*	1.00						
(3) Broadband	–0.07*	0.76*	1.00					
(4) Age	–0.05*	0.13*	0.20*	1.00				
(5) Male	0.00	0.04*	0.06*	0.00	1.00			
(6) Post-secondary education	–0.00	0.15*	0.23*	0.03*	0.05*	1.00		
(7) Opportunity	–0.00	0.09*	0.13*	–0.04*	0.07*	0.14*	1.00	
(8) Technology sector	0.01	0.06*	0.08*	–0.01*	0.07*	0.09*	0.05*	1.00

* $p < 0.01$.

Table 3. Probit Regression Results

Dependent variable: ***Technology Entrepreneurship***

	1	2	3	4
Age	–0.0052***	–0.0060***	–0.0053***	–0.0060***
	(0.0005)	(0.0007)	(0.0005)	(0.0007)
Male	–0.0174	–0.0284*	–0.0168	–0.0285**
	(0.0133)	(0.0159)	(0.0133)	(0.0159)
Post-secondary education	0.0426***	0.0068	0.0402***	0.0052
	(0.0142)	(0.0165)	(0.0143)	(0.0164)
Opportunity	–0.0039	0.0051	–0.0028	0.0052
	(0.0146)	(0.0178)	(0.0146)	(0.0179)
Technology sector	0.1790***	0.1936***	0.1801***	0.1939***
	(0.0312)	(0.0336)	(0.0312)	(0.0336)
R&D expenses		1.0461***		1.0473***
		(0.2394)		(0.2409)
R&D expenses^2		–0.2158***		–0.2270***
		(0.0466)		(0.2409)
Broadband			0.0121***	0.0100***
			(0.0046)	(0.0061)
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Constant	–1.1944***	–0.8862***	–1.2548***	–1.0962***
	(0.1071)	(0.0336)	(0.0662)	(0.5374)
No. of observations	68032	50163	67818	50163
Wald Chi squ.	3049.93	1680.36	2892.05	1680.28
Log likelihood	–23211.942	–15862.497	–23058.69	–15861.114
McFadden's R^2	0.064	0.044	0.057	0.044
McKelvey & Zavoina's R^2	0.106	0.088	0.103	0.088

Notes: Models 1–4 report the results for the probit model using the robust estimator of variance. All models are based on the 2005–10 period. The sample size varies across models because of missing values. Main results are similar when the estimations are conducted on samples with the same number of observations. Coefficients on country and year dummies are not reported. Standard errors appear in parentheses. *** $p < 0.001$, ** $p < 0.01$ and * $p < 0.05$. 'Yes' for year and country dummies indicates that these dummies are included in the regressions.

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data. However, pseudo-R^2 in probit estimations cannot be interpreted as R^2 in ordinary least squares (OLS) because these do not correspond to the percentage of explained variance (Hoetker, 2007). We compute the variance inflation factor (VIF) for each of the regression coefficients to test whether there is multicollinearity. Results show that multicollinearity does not impact the results because no VIF value is larger than 10 (VIF values range between 1.07 and 8.23). As Table 3 shows, the estimated coefficient of *R&D expenses* is positive, whereas the coefficient of the quadratic term is negative (columns 2 and 4). This result indicates that our hypothesis concerning the existence of an inverted U-shaped relationship between the R&D variable and technology entrepreneurship (H1) is validated.

With regard to the influence of access to ICT infrastructure on technology entrepreneurship, the positive coefficient of *Broadband* confirms the existence of a positive relationship between the two variables (columns 3 and 4). H2 is therefore validated.

In addition, the estimated coefficients for some control variables are noteworthy. First, our findings suggest that the personal characteristics of entrepreneurs, such as age and education, impact the likelihood of technology entrepreneurship. The estimated coefficient of *Age* is negative and thus indicates a negative relationship between technology entrepreneurship and age. Moreover, the estimated coefficient of the *Technology sector* variable is significant and positive in all estimations. This implies that technology entrepreneurship is more likely to occur in medium- or high-technology sectors.

Discussion

The influence of the technological environment at country level on the likelihood of technology entrepreneurship is an important, yet so far insufficiently investigated issue. Our study contributes to fill this research gap by examining the relationship between the technological environment, measured by R&D expenditure at national level and access to ICT infrastructure, and the likelihood that an individual will engage in technology entrepreneurship. We do so by using a large data set covering 54 countries and 68,032 individuals.

We find support for both of our hypotheses. Hypothesis 1 states that there is an inverted U-shaped relationship between R&D expenditure and the likelihood of technology entrepreneurship. Our results confirm the existence of such a relationship. This result is highly significant for technology entrepreneurship research because it confirms the existence of a strong relationship between the technological environment and the likelihood of technology-based firm creation.

We provide empirical support for the arguments of the knowledge spillover theory of entrepreneurship (Acs et al., 2009; Acs, Audretsch & Lehmann, 2013). This theory suggests that the knowledge resulting from investment in education and R&D at country level can be used by entrepreneurs to start new ventures. While in their empirical demonstration Acs et al. (2009) focus on the level of entrepreneurship in a country as a result of R&D investment, our study investigates more specifically technology entrepreneurship, and it identifies a strong relationship between R&D investment and the likelihood that entrepreneurs will create technology-based ventures. Our results thus show that technology entrepreneurship will develop in settings characterized by moderate levels of R&D investments. Conversely, countries in which R&D investment is very low or very high offer little opportunity for technology firm creation. This implies that in order for technology entrepreneurship to proliferate, there should be a certain level of R&D, but that if the level becomes too high, opportunities for technology entrepreneurship are reduced, probably because research and technology is concentrated in incumbent firms. This finding is consistent with the distinction between entrepreneurial and routinized technological regimes, as it suggests that in routinized regimes large firms dominate the innovation and new technology landscape, leading to few opportunities for entrepreneurial firms.

Our result is in line with a number of insights from previous studies (Orr, 1974; Audretsch, 1995; Acs et al., 2009; Minniti & Lévesque, 2010). Choi and Phan (2006) thus find that economic concentration deters new firm entry and conclude that 'highly concentrated economies are characterized by diversified firms that expand to fill market niches which would normally be exploited by small start-ups, [and] crowd out their smaller counterparts' (p. 495). Our study confirms this finding, which appears to be especially applicable to technology entrepreneurship.

Our second hypothesis states that access to ICT is positively related to the likelihood of technology entrepreneurship. This hypothesis is also validated. This result is not surprising, because it concurs with previous findings demonstrating the importance of access to ICT for entrepreneurial firms (Loane, 2006; Etemad, Wilkinson & Dana, 2010), especially in developing countries (Singh, 2009). Indeed, it is well known that the ICT infrastructure in

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emerging countries lags behind that in developed countries (Kiss, Danis & Cavusgil, 2012). Our research shows that access to ICT strongly determines the likelihood of technology entrepreneurship, which implies that measures taken to improve access to ICT infrastructure could have a significant impact on a country's rate of technology entrepreneurship.

Our results concerning the three control variables are also interesting. First, we find a negative relationship between age and technology entrepreneurship. This finding confirms the theoretical (Lévesque & Minniti, 2006) and empirical (Reynolds et al., 2004; Lamotte & Colovic, 2013) evidence indicating that relatively younger individuals are more likely to start a new business, one of the reasons being that they are more inclined to take risks than older individuals. Furthermore, prior research suggests that younger individuals are more likely to be creative, open-minded and oriented towards new technologies than the older individuals (Ruth & Birren, 1985). Indeed, the ability of an individual to be creative decreases with age because people are influenced by their experience and this reduces their creative abilities (Ruth & Birren, 1985; Colovic & Lamotte, 2012).

Second, the positive estimated coefficient of *Post-secondary education* indicates that educated individuals are more likely to enter technology entrepreneurship; this finding also concurs with the results of previous studies (Arenius & Minniti, 2005; Aidis, Estrin & Mickiewicz, 2012).

Third, we find that technology entrepreneurship is more likely to occur in high-technology sectors than in low-technology sectors, which confirms the findings of Thornhill (2006). This result is not as obvious as it may seem, since technology entrepreneurship can occur in all sectors, including agriculture or retail services. There are perhaps two plausible explanations for this result. First, because the speed of technological change is higher in the technological sector than in other sectors, this sector provides more opportunities for new firm entry. Second, individuals who work in the technological sector are likely to be more sensitive to new technologies and their market value. Because entrepreneurial activity is more likely to occur in sectors in which individuals possess skills and experience, this activity is more likely to occur in the technological sector.

Conclusions

Based on a study of entrepreneurial activity in 54 countries, this research provides empirical evidence for the influence of the technological environment on technology entrepreneurship. Therefore, this study contributes to the stream of literature that explores the ways in which the environment shapes entrepreneurship (Wennekers et al., 2005; Acs, Desai & Hessels, 2008; Aidis, Estrin & Mickiewicz, 2008, 2012; Stenholm, Acs & Wuebker, 2013; Laplume, Pathak & Xavier-Oliveira, 2014). This research identifies a significant, robust inverted U-shaped relationship between R&D investment and the likelihood of technology entrepreneurship. Low and very high levels of R&D in a country lead to lower rates of technological entrepreneurial entry, whereas a moderate level of R&D positively affects the creation of new technology-based firms. Our results also indicate that in order for technology entrepreneurship to proliferate, individuals should have access to ICT infrastructure. Moreover, we show that technology entrepreneurs are more likely to be young individuals with a high level of education and that technology entrepreneurship is more likely to occur in the technological sector.

This study contributes to the existing literature by identifying certain contextual factors that explain the differences in the extent of technology entrepreneurship across countries. Major policy implications emerge from our results. First, our findings imply that public R&D expenses might not lead to new technology-based venture creation. It therefore follows that governments that are interested in fostering technology entrepreneurship should create policies for stimulating such entrepreneurship in those environments in which it is less likely to occur. Specific subsidies could, for example, be reserved for the creation of technology-based ventures. Policies should also facilitate access to foreign, external knowledge in those settings in which knowledge spillovers are insufficient. Second, our results suggest that investing in ICT infrastructure such as broadband Internet is a necessary condition for the development of technology entrepreneurship.

This study has some limitations that should be considered when interpreting the results. First, the decision to use data pertaining to R&D expenditure as a measure of the technological environment is subject to criticism because it does not account for productivity (Koellinger, 2008); R&D investment might not necessarily lead to new knowledge creation because some R&D projects generate no output. However, in a large sample, R&D expenditure and R&D output are likely to be highly correlated. Second, our *Technology entrepreneurship* variable is based on the information provided by individual respondents

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to GEM teams. Nevertheless, this limitation should be nuanced, as we are not interested in objective technology but rather seek to investigate entrepreneurs' perceptions of opportunities. Moreover, other recent studies also use this GEM variable in their empirical estimations (see, e.g., Laplume, Pathak & Xavier-Oliveira, 2014). Third, the large size of the sample might also be criticized, as the likelihood of finding significant relationships between variables increases with sample size. However, the use of GEM data is widespread in the academic literature today, and a number of recent studies on technology entrepreneurship are based on this dataset (Pathak, Xavier-Oliveira & Laplume, 2013; Laplume, Pathak & Xavier-Oliveira, 2014). We therefore believe that GEM data is appropriate for investigating entrepreneurship-related issues.

The limitations of our study call for further research to refine both the explained and explanatory variables. Further research directions could be envisaged to better understand the role of the context in new venture creation and growth. One particularly interesting and purposeful extension of this study would be an attempt to distinguish the effects of public R&D investment from those of private R&D on technology entrepreneurship.

Appendix: Countries Included in the Empirical Study

Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Croatia, Czech Republic, Denmark, Ecuador, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Korea, Latvia, Malaysia, Mexico, Netherlands, New Zealand, Norway, Peru, Philippines, Poland, Portugal, Russia, Singapore, Slovenia, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, Uganda, United Arab Emirates, United Kingdom, United States, Uruguay and Venezuela

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Ana Colovic (ana.colovic@neoma-bs.fr) is an Associate Professor at NEOMA Business School, France. She holds a PhD from the University of Paris Dauphine. She conducts research in the fields of International Business, Strategy and Entrepreneurship.

Olivier Lamotte (olamotte@esg.fr) is an Associate Professor of International Business and the Head of the Research Department 'Economic and Financial Performances' at Paris School of Business, France. He holds a PhD from the University of Paris 1 Pantheon Sorbonne. As a team member of the Chair New Practices for Innovation and Creativity, he conducts research on internationalization and innovation of firms.

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