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Full Length Research Paper

Impact of entrepreneurial activity on technological innovation in emerging and developing countries

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The present study examines the impact of entrepreneurial activity on technological innovation in emerging and developing countries. For this purpose, we use the Global Entrepreneurship Monitor data for the entrepreneurial activity, while technological innovation is measured by US patent applications. Linear regressions are applied on data for 15 countries during the period 2009-2012. Findings show that total entrepreneurial activity decreases the innovation level. On the other hand, opportunity driven entrepreneurship stimulates international patenting. Furthermore, findings show that entrepreneurship is beneficial only in favourable institutional environment, in particular free trade and control of corruption. The main implication of our study is that policy makers should not only encourage entrepreneurship but also provide high quality institutions in order to enhance the level of technological innvation in emerging and developing countries. To the best of our knowledge, this is the first paper which considers many dimensions of entrepreneurship and examines the implication of these different dimensions for technological innovation. In addition, our study is the first to examine the interaction between entrepreneurship and innovation in the context of emerging and developing countries.

Keywords: innovation, total entrepreneurial activity, opportunity driven entrepreneurship, institutions, developing and emerging countries

JEL Classification: O3, L26, O25

INTRODUCTION

With the importance of knowledge as a prime driver of economic growth, initiatives aim to enhance a nation's knowledge capacity. Efforts are targeted to strengthen economic and social dimensions of the country as key determinants for successful transition to knowledge economy. This study adds to the literature by examining the contribution of entrepreneurship in shaping the knowledge economy. Its objective is to evaluate the impact of entrepreneurial activity on technological innovation in emerging and developing countries.

Entrepreneurship is increasingly seen as a key determinant of economic development (Baumol 1990; Wennekers and Thurik 1999; Minniti and Lévesque 2008). Theoretical and empirical contributions have long established that innovation promotes economic development and economic growth (e.g., Aghion and Howitt, 1992; Romer, 1990; Fagerberg et. al., 2007). Hence, there seemed to be a consensus on the importance of entrepreneurship and innovation for all countries whatever their advancement level. However, studies highlighting the relationship between these two elements are very scarce. To the best of our knowledge, two empirical works have studied the role of entrepreneurial activity in the innovation capacity: Draghici and Albulescu (2014) for a sample of developing and developed countries and Albulescu and Draghici (2016) for a sample of European countries.

Our study deals with this neglected issue in the literature. It aims to answer the following questions: How does entrepreneurship affect the technological innovation level? Do small entrepreneurial firms contribute to the innovation level? Are they able to increase innovation whatever the conditions? Do all types of entrepreneurship increase innovation?

Our study aims to answer these questions by applying linear regressions on panel data relative to 15 developing and emerging countries over the period 2009-2012. Our estimated results show that entrepreneurship decreases the innovative activities. It increases technological innovation only in countries with high quality institutions. Moreover, findings show a positive and significant effect of opportunity driven entrepreneurship on innovation.

The rest of the paper is organized as follows:

Literatuew review which discusses theoretical issues and empirical results relative to previous studies in order to state our research hypotheses; Empirical methodology; Discussion of empirical findings and then Conclusion.

Literature review and research hypotheses

The concept of entrepreneurship seems to be multi-dimensional (Spencer and Gomez, 2004). It includes many facets. Some are related to the creation or discovery of opportunities, others are related to self-employment and others to innovation. In the present paper, the entrepreneurship is defined as the creation of new firms. Moreover, we recognise that it includes many types, as pointed out by the Global Entrepreneurship Monitor studies (opportunity driven entrepreneursip vs necessity driven entrepreneursip) and Baumol (productive vs unproductive). We will refer to these different dimensions of entrepreneurship to examine their implications for technological innovation.

Creation of new firms and innovation

A substantial body of literature confirms that small entrepreneurial firms are not able to generate innovation. Schumpeter's hypothesis says that larger firms innovate more because of their ability to access to funds and spread Research and Development (R&D) risk (Alsharkas, 2014). Cohen (2010) claims that R&D is alleged to be more productive in large firms as a result of complementarities between R&D and other non-manufacturing activities (such as marketing and financial planning) that may be better developed within large firms.

On the other hand, it is argued that smaller firms may be less bureaucratic, more flexible and therefore more efficient at innovation (Palangkaraya et al. 2016). In addition, smaller firms could take decisions quicker and rapidly response to market changes (Matras-Bolibok, 2014).

Empirical evidence reflects these two conflicting views. Some studies have found that firm's size is associated with increased innovative activities; while others have found a negative relationship between firm's size and innovation. In some other empirical works, the impact of the small entrepreneurial firms on innovation has been found to be weakly significant or insignificant.

Based on the business environment and enterprise performance survey for 1053 enterprises from twenty-six countries in years 2002 and 2005, Alsharkas (2014) found a positive and statistically significant relationship between firm size and innovation. Arias-Aranda et al. (2001) studied the influence of firm size over degree of innovation in a service sector, specifically in engineering consulting and technology services in Spain. Results seem to indicate that firm size, measured by turnover, is related positively with the degree of innovation. Matras – Bolibok (2014) assessed the impact of firm's size on the innovative performance especially during the period of recent global economic crisis, basing on the results of the analysis conducted for Polish industrial enterprises. The results of his analysis indicate that larger enterprises achieved better results of innovative activity. Elshamy (2015) demonstrated that there is a positive relationship between firm size and innovation in Egypt during the period 2010-2012.

In contrast with these studies, results of some empirical works suggest that smaller firms innovate more than larger ones or have not a significant impact on innovation. For example, Acs and Audretsch (1987) found that the small-firm innovative advantage tends to occur in industries in the early stages of the life-cycle, where total innovation and the use of skilled labor play a large role, and where large firms comprise a high share of the market. Prusa and Schmitz (1990) examined data from the PC software industry over the period 1982-1987. They found that new firms have a comparative advantage (over established firms) in creating new software categories, while established firms have a comparative advantage in developing subsequent improvements in existing categories. Based on data collected through personal interviews involving 209 industrial firms in the northern part of Israel, Shefer and Frenkel (2005) found that the small-size firms engage more intensively in R&D activities than do the large firms. However, when the sample was stratified into two distinct group of firms, high-tech and traditional, then hightech plants show a highly negative statistically significant association. For the traditional group of firms, no statistically significant result was observed. Johansson and Loof (2008) and Lee (2009) found that firm size is in general negatively related to firm R&D intensity. Draghici and Albulescu (2014) conducted a panel data analysis for 34 developed and developing countries for the period 2009-2012. Their results show that the overall entrepreneurial activity does not influence the national innovative capacity. Albulescu and Draghici (2016) assessed the role of entrepreneurship in strengthening the national innovative capacity of the European countries. They used the Global Entrepreneurship Monitor data for the entrepreneurial activity, while the innovative capacity was measured by the Global Innovation Index and the Summary Innovation Index. Their panel data estimations for the period 2009-2012 show that the total entrepreneurial activity does not influence the national innovative capacity.

In view of these arguments, we cannot predict a sign for the impact of small entrepreneurial firms on innovation. Thus, we formulate the following hypotheses:

- H1a: The entrepreneurial activity will increase the level of technological innovation.
- H1b: The entrepreneurial activity will decrease the level of technological innovation.

Opportunity driven entrepreneurship and innovation

Global Entrepreneurship Monitor (GEM) studies employ two categories of entrepreneurship: opportunity driven entrepreneurship (ODE) and necessity driven entrepreneurship (NDE). Necessity driven entrepreneurship is about creating something that already exists. In this case, entrepreneurs have no job, they have not high qualifications and their financial resources are limited. Entrepreneurial activity is considered as a source of revenue (Singer et al., 2015). Therefore, it is hard to associate it with the innovation process (Albulescu and Draghici, 2016).

In contrast, opportunity driven entrepreneurship is the case when entrepreneurs found a new firm to exploit an opportunity. According to Casson (1982), entrepreneurial opportunities are the situations in which new goods, services, raw materials, and organizing methods are introduced and sold at greater than their cost of production. Schumpeter (1934) highlights the central role of the entrepreneur in the innovation process. He points out that entrepreneurship occurs when there is an innovation. This means that entrepreneurship is linked to the creation of new combinations: the introduction of new product, the introduction of new production process, the use of new raw materials, the establishment of a new organisation or the conquest of new markets. The definition of Schumpeter implies that only this category of entrepreneurship may contribute to the national innovation level.

To the best of our knowledge, two empirical works have studied the role of opportunity driven entrepreneurship in the innovation capacity: Draghici and Albulescu (2014) found a positive and significant impact of ODE on national innovative capacity of developing and developed countries. Albulescu and Draghici (2016) did not find a significant impact of opportunity driven entrepreneurs on the national innovative capacity of European countries in the period 2009-2012.

In view of Schumpeter's definition of entrepreneurship, we predict:

- H2: The opportunity driven entrepreneuship will increase the level of technological innovation.

Institutions, entrepreneurship and innovation

As Schumpeter, Kirzner (1978) assigns a major role to the entrepreneur as an innovator and an agent of change. But, he emphasizes that entrepreneur is interested in discovering profit opportunities. Hence, the main question to ask is how to discover and exploit these opportunities. One answer to this question may be the market institutions. Therefore, innovation depends on institutions.

In his article "Entrepreneurship: Productive, Unproductive and Destructive", Baumol (1990) distinguishes between several forms of entrepreneurship. He points out that entrepreneurs are defined as ingenious and creative people who find ways to add value to their own wealth, power and prestige. The general environment plays an important role in determining the type of entrepreneur which can be productive or unproductive. According to Baumol, the choice of the entrepreneur between good and bad business depends on their relative performance. Therefore, there must be adequate incentives and institutions to better remunerate productive entrepreneurship. Productive entrepreneurship is encouraged by encouraging entrepreneurs to invest in productive innovation instead of rent seeking (the unproductive search for economic profit) or even destructive occupations such as criminal activities. Thus, Baumol distinguishes between different types of entrepreneurs and focuses on the important role that the institutional context can play in the determination of productive entrepreneurship.

According to North (1991), institutions are the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct) and formal rules (constitutions, laws, property rights).

Entrepreneurs will adapt their activities and strategies according to the opportunities and limitations of the formal and informal institutional framework. Johnson et al. (2002) studied small manufacturing firms in Eastern Europe. They found that weak property rights and legal systems discourage entry of new firms. Desai et al. (2003) analyzed institutions and entrepreneurial activity in Europe and found that there is more entrepreneurship in less corrupt countries and in countries with better property rights among the emerging economies in Eastern Europe. However, this effect is attenuated for the advanced economies in Western Europe.

Furthermore, institutions and quality of governance greatly influence innovation. Sala-i-Martin (2002) argues that it is difficult to find new and better technologies if an economy does not have the right institutions. Freeman (1987) shows that the quality of institutions is a key element in the process of creating and disseminating new technologies. Indeed, in the absence of institutions, companies undertake myopic innovative processes which lead to short-term profit maximization, but do not allow them to maximize long-term profits. As a result, appropriate institutions can provide firms with adequate incentives for innovation by altering their behavior in short time, which is a motivation to engage in innovative processes that ensure long-term profitability. According to Oyelaran-Oyeyinka (2004), institutions can mitigate the uncertainty of innovation activities by providing regulations governing economic agents and requiring them to comply with contractual obligations. Oyelaran-Oyeyinka (2006) showed that several African countries have adopted the industrialization model of developed countries, but fail to achieve technological progress because of their weak institutional framework.

One methodological problem concerns the measurement of the institutional environment. As inprevious empirical works, in the present study, institutions and quality of governance are represented by economic freedom and control of corruption.

Economic freedom affects incentives, productive effort and the effectiveness of resource use. De Haan and Sturm (2000) note that since the time of Adam Smith, economists have argued that the freedom to choose and supply resources, competition in business, trade with others and secure property rights are central ingredients for economic progress. When entrepreneurs face higher regulations and higher costs of business, new ideas and business ventures are less likely to occur (Boudreaux, 2017). Using a representative sample of 32832 firm-year observations from 29 countries over the 1984-2006 period, Zhu and Zhu (2017) found that the economic freedom index is positively associated with the number of citations per patent, patents, originality and generality. Furthermore, they found a positive relationship between corporate innovation and freedom from corruption, fiscal freedom, government spending, labor freedom, trade freedom and financial freedom. Boudreaux (2017) argues that market institutions may help explain the variation in the levels of innovation among countries. He points out that by reducing transactions costs and establishing good governance, high quality market institutions may foster an environment more nurturing of innovation. His study shows that economic freedom matters for innovation through both creativity and knowledge, particularly through the protection of property rights and the legal system and free trade.

Control of corruption affects positively the innovation level. In fact, according to “sanding the wheels” hypothesis, corruption discourages R&D investment because it increases both the distrust and the transaction costs (Shleifer and Vishny, 1993; Murphy et al., 1991, 1993; Mauro, 1995). However, this negative effect is denied by the “greasing the wheels” hypothesis, according to which corruption may have some advantages to innovation. Indeed, corruption allows entrepreneurs and innovators to overcome bureaucratic obstacles and to easily access crucial resources for innovation activities such as permits and licenses (Leff, 1964; Leys, 1965). Empirical literature confirms these two opposing hypotheses. On one hand, Mahagaonkar (2008) and Anokhin and Schulze (2009) found a negative relationship between corruption and innovation. On the other hand, Meon and Weill (2010) and Anh Nguyen et al. (2016) found a positive impact of corruption on innovation. Although the divergent points of view, we adopt in this study the “sanding the wheels” hypothesis and assume that control of corruption encourages innovation.

In view of the arguments cited above, we predict that the impact of entrepreneurship on technological innovation depends on institutions: the higher the quality of institutions, the more likely entrepreneurship will enhance the innovation level.

- H3: The total entrepreneurial activity will increase the level of technological innovation more among countries with higher quality institutions compared to countries with lower quality institutions.

Other determinants of technological innovation

Endogenous growth theory emphasizes the role of knowledge stock and human capital in technological innovation. Previous studies identify other determinants of technological innovation in the context of emerging and developing countries, namely the sources of foreign knowledge represented in this paper by imports of technology and foreign direct investment (FDI).

The stock of knowledge is an important determinant of productivity (Coe and Helpman, 1995). On the other hand, the capacity of a nation to develop absorptive capacity depends heavily on previous knowledge investments. The initial investment makes it possible to make better technological choices and to better exploit new possibilities (Cohen and Levinthal, 1990).

The empirical studies of Porter and Stern (2000), Furman et al (2002), Schneider (2005) and Teixeira and Fortuna (2010) found a positive and significant impact of the stock of knowledge on technological innovation.

Human capital is seen as an important source of competitive advantage for individuals, organizations and societies (Coleman, 1988; Gimeno et al., 1997). Qualified people have a great ability to learn new skills, to adapt to changing circumstances and to do things differently. In addition, well-qualified people generate knowledge that can be used to create and introduce an innovation.

Many empirical works confirm a positive relationship between human capital and innovation (Gumbau-Albert and Maudos, 2009; Furman et al. 2002; Ulku, 2007; Griffith et al. 2004).

In the context of developing countries, a context of technological catch-up, innovation critically depends on the country’s links with the rest of the world. The acquisition of technologies in these countries depends on the transfer of technology. Mechanisms of technology transfer are numerous: Foreign direct investment, international trade, licensing contracts, ...

In this study, we are interested in imports of foreign technologies and FDI. Imports of foreign technology stimulate technological innovation in emerging and developing countries. According to Loukil (2016), the technological know-how anchored in imported goods allows companies to use more efficient production processes and increase subsequently the quality of their own products and processes. Moreover, Salomon and Shaver, (2005) underline that the contact with suppliers is beneficial for local businesses. Bertschek (1995) found a positive effect of imported technologies and innovation in Germany.

Foreign direct investment helps to influence technological innovation in host countries through several mechanisms: Upstream linkages, downstream linkages, competitive effect, demonstration effect, effects on human capital formation and knowledge dissemination through brains (Berger and Diez, 2008). However, multinational companies (MNC) are sometimes not ready to transfer the most advanced technologies because they fear loss of intellectual property and future competition from companies learning new technologies (Hayter and Han, 1998). In addition, the technological capacities of the beneficiary firms in developing countries and the skills of their employees often p+revent the immediate understanding of advanced technologies (Cohen and Levinthall, 1990).

Given these arguments, it is not surprising that the results of the empirical works on the impact of FDI on innovation are mixed. Sjoholm (1999) and Cheung and Lin (2004) found positive effects of FDI on innovation. On the other hand, Aitken and Harrison (1999) and Chen (2007) did not find any significant relationship between the two variables.

METHODOLOGY

In this section, we first describe our sample. Next, we will define the variables used and their respective measures. Then, we will advance descriptive statistics. Finally, we will present the statistical models used in this study.

Sample selection: The present study examines a sample of 15 emerging and developing countries[i] for the period 2009-2012. This choice is justified by the availability of data.

Selection of variables and measurement instruments: We will present below the variables and their measures. It is necessary to specify the dependent variable as well as the independent variables of the models to be estimated.

Dependent Variable: While technological innovation cannot be accurately measured, patenting is often considered an appropriate proxy to the level of innovation (Griliches, 1990; Kanwar and Evenson, 2003; Furman et al., 2002).

The choice of patents as a representative variable of the output of innovation is justified by several advantages. The first advantage is the availability of very long time series for nations and regions. The second relates to patent databases that are publicly available and are increasingly computer-readable. The data are classified in detail by technical field. In addition, patent applications provide the most comprehensive and detailed overview of technical knowledge over long periods of time.

However, this measure has some limitations. On the one hand, the patent indicator lacks several non-patented inventions since some types of technologies are not patentable. On the other hand, patents filed do not measure the economic value of technologies (Hall et al., 2001; Acs et al., 2002; Grasjo, 2004).

In the absence of more reliable data, we use data from the US Patent and Trademark Office (USPTO). Our measure of technological innovation is the number of patent applications filed by residents of a given country with the USPTO. Because of the time lag between the filing process and the granting of a patent[ii], using data on patent applications rather than granted patents reflects the more immediate and faster innovative activity. Data on patent applications are transformed by taking their natural logarithms. Therefore, the dependent variable (PAT) is defined as the logarithm of the number of patent applications filed by a country's residents with the USPTO for a given year.

As the level of international patenting is observed with a time lag, our empirical work requires a lag of 2 years between explanatory variables and the dependent variable. Therefore, data for independent variables are for the period 2009-2012, and patent applications relate to the period 2011-2014.

Independent variables: Entrepreneurship is measured with reference to GEM data which are quite popular in entrepreneurship analysis because they rely on a considerable number of countries and distinguish different types of entrepreneurs. Total Entrepreneurial Activity (TEA) is defined in Singer et al. (2015, p 24) as the total early-stage entrepreneurial activity which represents the percentage of individuals aged 18-64 who are either a nascent entrepreneur or owner-manager of a new business.

Opportunity driven entrepreneurship (ODE) is the improvement driven opportunity entrepreneurship defined in the GEM report. It represents the percentage of individuals involved in early-stage entrepreneurial activity who (1) claim to be driven by opportunity as opposed to finding no other option for work; and (2) who indicate that the main driver for being involved in this opportunity is being independent or increasing their income, rather than just maintaining their income (Singer et al., 2015, p 24).

The institutional framework is measured by economic freedom and control of corruption.

Data on economic freedom are extracted from the Heritage Foundation. To avoid the problem of correlation between many compounds of economic freedom, we choose two variables: business freedom and trade freedom.

Business freedom is about an individual's right to create, operate, and close an enterprise without interference from the state. Thus, BUSF is the variable reflecting the procedures involved in running a business, it ranges between 0 and 100 (100 represents the maximum degree of business freedom).

Trade freedom reflects the openness of an economy to imports of goods and services from around the world and the ability of citizens to interact freely as buyers and sellers in the international marketplace. TRDF is the measure related to trade barriers, it ranges between 0 and 100 (100 represents the maximum degree of trade freedom).

Data on control of corruption are extracted from Transparency International.

Transparency International defines corruption as the abuse of entrusted power for private gain. This definition encompasses corrupt practices in both the public and private sectors. The Corruption Perceptions Index (CPI) ranks countries according to perception of corruption in the public sector. It takes value between 10 (highly clean) and 0 (highly corrupt).

To measure the stock of knowledge, we use the variable patent stock which is the sum of patents until time t – 1. This same measure was used by Porter and Stern (2000). Data are transformed by taking their natural logarithms and are from USPTO.

Human capital (HC) is measured by total R&D personnel per million inhabitants. Data are transformed by taking their natural logarithms and are from UNESCO Database.

Imports of technologies (IMP) are measured by the level of imports of high-tech goods. This metric is used by Schneider (2005). The product groups included in this measure are products in classes 7, 86 and 89 of the Standard International Trade Classification (SITC, Rev. 1)[iii]. Data are collected from United Nations Commodity Trade Statistics Data Base. In order to express this variable in real terms, the data are deflated by the US Producer Price Index (PPI) for capital equipment (Source: Bureau of Labor Statistics). Data are transformed by taking their natural logarithms.

In the present research, we use the same measure used by Teixeira and Fortuna (2010) to estimate the effect of foreign direct investment on innovation. This is the variable (FDI), which refers to the share of inward FDI flows in GDP. Data are from World Bank's World Development Indicators.

Descriptive statistics

Table 1 provides the descriptive statistics on the number of patents as well as the explanatory variables (TEA, ODE, BUSF, TRDF, CPI, PATS, HC, IMP, FDI).

The countries of our sample have an average level of patents filed with the USPTO equal to 210.8. Regarding their dispersion, patents reach 1007 for some countries while they are zero for others. Concerning entrepreneurial activities, on average, 11.4% of the population aged 18-64 are entrepreneurs. Opportunity driven entrepreneurs represent around 42.2 % of total entrepreneurs.

To better understand the distribution of patents and entrepreneurial activities in the countries of our sample, we present the figures below.

According to these figures, we observe that Russia has the highest average number of patents (893.25), while Macedonia and Guatemala are the least innovative countries in our sample with a mean equal respectively to 1.5 and 2.25 patent applications during the period 2011-2014.

Ecuador has the highest percentage of individuals engaged in an entrepreneurial activity with a mean of 22% during the period 2009-2012. Russia and Malaysia are the countries which report the fewest volume of entrepreneurship with a mean percentage equal to 4% and 5.3% respectively. Observing Figure 1 and Figure 2, it is clear that there is no relationship between entrepreneurial activity and innovation in Russia, which has the highest level of technological innovation and the least level of entrepreneurship. We conclude that several factors contribute to the innovation in this country other than entrepreneurship.

From the Figure 3, we can observe that Chile and Malaysia are the countries which have the highest average percentage of opportunity driven entrepreneurs during the period 2009-2012 (54.6% and 54.4%, respectively). On the other hand, Macedonia has the lowest share of ODE in our sample with a mean of 25.2%.

Statistical models

In order to test the hypotheses H1a and H1b, the following model is estimated:

$$PAT_{it+2} = \beta 0 + \beta 1\ TEA_{it} + \beta 2\ BUSF_{it} + \beta 3\ TRDF_{it} + \beta 4\ CPI_{it} + \beta 5\ PATS_{it} + \beta 6\ HC_{it} + \beta 7\ IMP_{it} + \beta 8\ FDI_{it} + \varepsilon_{it} \quad (1)$$

In order to test the hypothesis H2, the following model is estimated:

$$PAT_{it+2} = \beta 0 + \beta 1\ ODE_{it} + \beta 2\ BUSF_{it} + \beta 3\ TRDF_{it} + \beta 4\ CPI_{it} + \beta 5\ PATS_{it} + \beta 6\ HC_{it} + \beta 7\ IMP_{it} + \beta 8\ FDI_{it} + \varepsilon_{it} \quad (2)$$

In order to test the hypothesis H3, we introduce in (1) interaction terms TEA*BUSF, TEA*TRDF and TEA*CPI (three new variables: TEABF, TEATF and TEAC). So, we estimate the following model:

$$PAT_{it+2} = \beta 0 + \beta 1\ TEA_{it} + \beta 2\ BUSF_{it} + \beta 3\ TRDF_{it} + \beta 4\ CPI_{it} + \beta 5\ TEABF_{it} + \beta 6\ TEATF_{it} + \beta 7\ TEAC_{it} + \beta 8\ PATS_{it} + \beta 9\ HC_{it} + \beta 10\ IMP_{it} + \beta 11\ FDI_{it} + \varepsilon_{it} \quad (3)$$

i = 1, 2, …., 15; t = 1,…., 4.

PAT = Ln(number of patent applications filed in the USPTO) ; TEA = Total entrepreneurial activity; ODE = Percentage of opportunity driven entrepreneurs; BUSF = Business freedom index; TRDF = Trade freedom index; CPI = Corruption perception index; TEABF = TEA*BUSF; TEATF = TEA*TRDF; TEAC = TEA* CPI; PATS = Ln(stock of patents); HC = Ln(total R&D personnel per million inhabitants); IMP = Ln(imports of high tech goods deflated by US PPI for capital equipment); FDI = Foreign direct investment inflows (%GDP); ε is regression residuals. Linear models are estimated by the software STATA 12.

Table 1. Summary statistics

Variable	Average	Median	Standard deviation	Minimum	Maximum
PAT	210.8	101.5	276.8	0	1007
TEA	11.4	9.1	6.4	3.9	27
ODE	42.2	42	10.6	23	71.8
BUSF	66.6	67.9	9.8	48.5	82.9
TRDF	77.5	78.5	9.6	53	88
CPI	4.02	4.05	1.1	2.1	7.2
PATS	2437.07	844.5	2929.1	11	9277
HC	1638.9	1428.5	1467.8	56.9	5911.8
IMP	2.02e + 0.8	1.29e + 0.8	2.32e + 0.8	7672215	1.01e + 0.9
FDI	3.1	2.7	3.8	-16.07	12.8

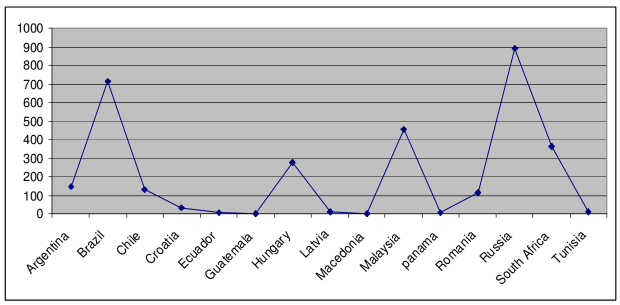

Figure 1. Number of patent applications filed with the USPTO of 15 countries (mean 2011-2014)

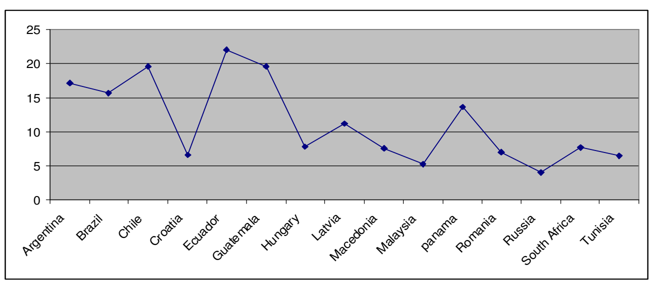

Figure 2. Total Entrepreneurial Activity of 15 countries (mean 2009-2012)

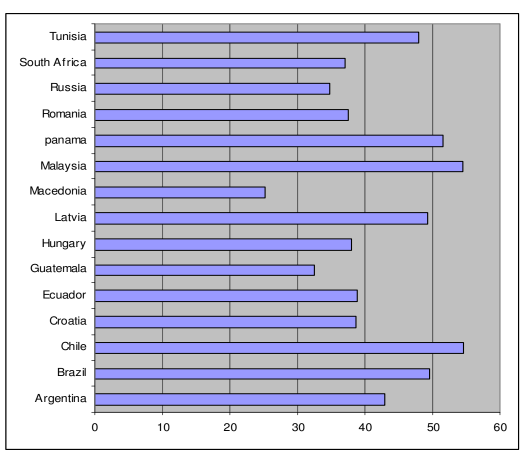

Figure 3. Percentage of opportunity driven entrepreneurs in total entrepreneurs of 15 countries (mean 2009-2012)

Table 2. Simple correlations between the dependent variable and the explanatory variables

Simple correlations with the variable log(number of US patent applications)		
Explanatory variables	**Predicted sign**	**Correlation**
TEA	+ / -	-0.278**
ODE	+	0.228*
BUSF	+	0.006
TRDF	+	-0.104
CPI	+	0.156
TEABF	+	-0.273**
TEATF	+	-0.299**
TEAC	+	-0.071
PATS	+	0.949***
HC	+	0.605***
IMP	+	0.948***
FDI	+/-	-0.079

*, ** and ***: significant correlations at 10%, 5% and 1% thresholds.

PRESENTATION AND INTERPRETATION OF RESULTS

Before presenting findings, we proceed to analyse the independence of the explanatory variables. This is the multi collinearity test. To check the condition of absence of multi-collinearity, we use the simple correlation matrix and assume a limit of 0.7. According to the correlation matrix, strongest correlations are found between the knowledge stock and imports of high tech goods, and between the terms of interaction between entrepreneurship and institutions. The correlation coefficient between PATS and IMP is equal to 0.92. The correlation coefficient between TEABF and TEATF is equal to 0.94. The correlation coefficient between TEABF and TEAC is equal to 0.84. The correlation coefficient between TEATF and TEAC is equal to 0.84.

Thus, these four sets of variables should not be introduced in the same model in order to guarantee reliability of results.

Analysis of simple correlations

We begin our analysis by examining simple correlations. The matrix of simple correlations allows us to examine the correlation coefficients in order to study the null hypothesis of the absence of correlation between two variables. Table 2 summarizes the results found.

The analysis of simple correlations shows that the variable relative to entrepreneurship (TEA) is negatively and significantly associated with the innovation level. As expected, ODE is positive and significant. Concerning the variables relative to institutional environment, we find that BUSF and CPI has the predicted positive sign, the trade freedom index is negative. However, all the three variables are not significant. Contrary to predicted signs, correlation coeffcients for the interaction terms between entrepreneurship and institutions are negative. In accordance with the predicted signs, the stock of patents, the human capital and the imports of high tech goods are positively and significantly associated with US patent applications. For the FDI variable, the correlation is negative but not significant.

Findings

Estimation results of Model 1 (The impact of TEA on innovation level): To test hypotheses H1a and H1b, we have estimated three models where the dependant variable is natural logarithm of patent applications filed in USPTO (PAT) and the explanatory variable of interest is total entrepreneurial activity. Before examining results, it is necessary to verify some tests applied on the panel data.

First, the homogeneous or heterogeneous specification of the data generating process should be checked. If the test performed (individual presence test) shows that there are individual specificities, the Ordinary Least Squares (OLS) method is inappropriate and in this case, we apply Hausman test to determine whether the coefficients of the two estimates (fixed and random) are statistically different. In models (1.1), (1.2) and (1.3) the Lagrange multiplier test gives values of 28.49; 28.39 and 17.46

Table 3. Results of model estimates (1)

Independent variables	Dependant variable: PAT					
	Specification (1.1)		Specification (1.2)		Specification (1.3)	
	Coef. β	SE	Coef. β	SE	Coef. β	SE
Constant	-3.737	1.128***	-20.184	1.549***	-2.947	1.113***
TEA	-0.024	0.011**	-0.043	0.013***	-0.028	0.012**
BUSF	0.006	0.008			-0.002	0.009
TRDF	-0.0004	0.009			-0.007	0.009
CPI			0.168	0.092*	0.131	0.089
PATS	0.848	0.053***			0.835	0.047***
HC	0.307	0.098***	0.194	0.117*	0.303	0.089***
IMP			1.234	0.094***		
FDI	0.006	0.012	-0.009	0.014	0.007	0.013
Observations	60		60		60	
F/Chi2	411.12***		285.05***		537.03***	
R2	0.95		0.94		0.96	

Coefficients and Standard Errors are given in this table.
*, **, *** : Coefficients are significant at 10 %, 5 % and 1 %.
PAT, TEA, BUSF, TRDF, CPI, PATS, HC, IMP and FDI denote respectively: LN(number of patent applications filed in USPTO), total entrepreneurial activity, business freedom index, trade feedom index, corruption perception index, LN(stock of patents), LN(total R&D personnel per million inhabitants), LN(imports of high-tech goods) and percentage in GDP of inflows of foreign direct investments.

respectively and the associated p-values are below the threshold of 1%. We then reject the null hypothesis of absence of specific effects, so it is necessary to introduce individual effects. The probability of the Hausman test in the three cases is greater than 1% (0.7442 in model (1.1); 0.0231 in model (1.2) and 0.0187 in model (1.3)). Based on the Hausman test, we choose the random effects model for all models.

The Breush-Pagan test allows us to detect heteroskedasticity. In models (1.1), (1.2) and (1.3) the probabilities of the test are equal respectively to 0.1915; 0.9891 and 0.1464 which are superior than 5%. We therefore conclude that there is not a problem of heteroskedasticity for these three models.

The Wooldridge test allows us to detect the auto-correlation whose null hypothesis is the absence of auto-correlation errors. In models (1.1), (1.2) and (1.3) the probabilities of the test are equal respectively to 0.0136; 0.0151 and 0.0087 confirming the presence of an auto-correlation error problem for all estimated models.

In the following, we present the results of the linear regressions with correction of the auto-correlation problem in all specifications. Table 3 provides the results of the three linear regression models.

In all specifications, the Fisher/Chi2 statistic testing the joint significance of the explanatory variables is significant at 1%. This allows us to reject the null hypothesis that the regression coefficients β are zero. Therefore, our models are globally significant.

According to the three specifications, the coefficient relative to total entrepreneurial activity is negative and significant at 1% thereshold. Interpreting the specification (1.3) (as it has the highest R2), the coefficient implies that an increase in the level of entrepreneurs by 1% decreases the number of patent applications filed in USPTO by around 0.03%. Thus, the entrepreneurial activity has a negative and significant impact on the technological innovation level. Therefore, the hypothesis H1b is verified and H1a is not confirmed. Our finding confirms that a raise of the number of new small firms causes a decrease in the level of international patenting among emerging and developing countries. This result is coherent with Schumpeterian hypothesis which stipulates that large firms are more able to innovate than small firms. It is consistent with previous empirical studies that find a positive relationship between firm size and innovation such as Alsharkas (2014), Arias-Aranda et al. (2001) and Elshamy (2015). However, our result is not coherent with Shefer and Frenkel (2005) in Israel and Albulescu and Draghici (2016) in the context of european countries.

Among institutional variables, we find that only control of corruption has a positive and significant effect on innovation. Concerning control variables, we note that the stock of knowledge, the level of human capital and the imports of high tech goods stimulate technological innovation in emerging and developing countries.

Estimation results of Model 2 (The impact of ODE on innovation level): To test the hypothesis H2, we have estimated four models where the dependant variable is natural logarithm of patent applications filed in USPTO (PAT) and the explanatory variable of interest is opportunity driven entrepreneurship.

In models (2.1), (2.2), (2.3) and (2.4) the Lagrange multiplier test gives values of 26.38; 24.48; 20.44 and 16.38 respectively and the associated p-values are below the threshold of 1%. We then reject the null

Table 4. Results of model estimates (2)

Independent variables	Dependant variable: PAT							
	Specification (2.1)		Specification (2.2)		Specification (2.3)		Specification (2.4)	
	Coef. β	SE	Coef. β	SE	Coef. β	SE	Coef. β	SE
Constant	-4.740	0.656***	-4.982	0.807***	-4.750	0.844***	10.717	6.734
ODE	0.008	0.003**	0.008	0.003**	0.008	0.004**	0.008	0.006
BUSF	0.001	0.005			-0.004	0.007	0.022	0.013
TRDF			0.001	0.008	0.002	0.008	-0.008	0.029
CPI			0.037	0.057	0.062	0.065	-0.102	0.151
PATS	0.872	0.029***	0.872	0.031***	0.870	0.031***		
HC	0.388	0.060***	0.389	0.056***	0.385	0.056***	0.374	0.542
IMP							-0.541	0.365
FDI	0.002	0.010	0.005	0.011	0.005	0.011	0.0007	0.011
Observations	60		60		60		45	
F/Chi2	935.80***		1053.85***		1068.52***		1.24	
R2	0.67		0.63		0.60		0.27	

Coefficients and Standard Errors are given in this table.
*, **, *** : Coefficients are significant at 10 %, 5 % and 1 %.
PAT, ODE, BUSF, TRDF, CPI, PATS, HC, IMP and FDI denote respectively: LN(number of patent applications filed in USPTO), opportunity driven entrepreneurship, business freedom index, trade feedom index, corruption perception index, LN(stock of patents), LN(total R&D personnel per million inhabitants), LN(imports of high-tech goods) and percentage in GDP of inflows of foreign direct investments.

hypothesis of absence of specific effects, so it is necessary to introduce individual effects.

The probability of the Hausman test in the first three cases is greater than 1% (0.2553 in model (2.1); 0.5524 in model (2.2) and 0.0966 in model (2.3). Based on the Hausman test, we choose the random effects model for these models. For the specification (2.4), the probability of the Hausman test is equal to 0.0000. So, we choose the fixed effects model for this model.

In models (2.1), (2.2) and (2.3), the probabilities of the Breush-Pagan test are equal respectively to 0.0443; 0.0439 and 0.0494 which are inferior than 5%. We therefore conclude that there is a problem of heteroskedasticity for these models. In model (2.4), the probability of the Breush-Pagan test is equal to 0.7924 which is superior than 5%. We therefore conclude that there is not a problem of heteroskedasticity for this fourth model.

In models (2.1), (2.2), (2.3) and (2.4) the probabilities of the Wooldridge test are equal respectively to 0.0197; 0.0200; 0.0101 and 0.0017 confirming the presence of an auto-correlation error problem for all estimated models.

In the following, we present the results of the linear regressions with corrections of the heteroskedasticity problem in the first three models and the auto-correlation problem in the four specifications. Table 4 provides the results of the four linear regression models.

In the first three specifications, the Chi2 statistic testing the joint significance of the explanatory variables is significant at 1%. This allows us to reject the null hypothesis that the regression coefficients β are zero. Therefore, these models are globally significant. The fourth model is not globally significant since the Fisher statistic is not significant. So, our interpretation will be based only on the first three models.

The coefficient of ODE is as expected positive and significant at 5% threshold. The coefficient implies that an increase in the level of opportunity entrepreneurs by 1% increases the number of patent applications filed in USPTO by around 0.008%. Our result is coherent with the Schumpeter's definition of entrepreneurship who argues that entrepreneurial activity is linked to the creation of new combinations. Thus, our second research hypothesis H2 is confirmed. Our finding corroborates that of Draghici and Albulescu (2014). We conclude that a raise in the number of opportunity entrepreneurs is beneficial to the country's innovative capacity of emerging and developing countries.

Concerning control variables, we note that the stock of patents and the human capital level have a positive and significant (at 1% threshold) impact on the level of international patenting.

Estimation results of Model 3 (The combined effects of TEA and institutions on innovation level): To test the hypothesis H3, we have estimated three models where the dependant variable is natural logarithm of patent applications filed in USPTO (PAT) and the explanatory variables of interest are the interaction terms between TEA and institutions.

In models (3.1), (3.2) and (3.3) the Lagrange multiplier test gives values of 17.05; 16.32 and 19.18 respectively and the associated p-values are below the threshold of 1%. We then reject the null hypothesis of absence of specific effects, so it is necessary to introduce individual effects.

The probability of the Hausman test in first and third cases is greater than 1% (0.0909 in model (3.1) and 0.0298 in model (3.3)). Based on the Hausman test,

Table 5. Results of model estimates (3)

Independent variables	Dependant variable : PAT					
	Specification (3.1)		Specification (3.2)		Specification (3.3)	
	Coef. β	SE	Coef. β	SE	Coef. β	SE
Constant	-2.903	1.552*	-8.747	3.885**	-2.327	1.162**
TEA	-0.03	0.081	-0.387	0.113***	-0.081	0.034**
BUSF	-0.002	0.015	0.023	0.011*	0.002	0.009
TEABF	0.00003	0.001				
TRDF	-0.007	0.009	-0.043	0.031	-0.006	0.009
TEATF			0.004	0.001***		
CPI	0.131	0.090	-0.061	0.138	-0.1	0.164
TEAC					0.013	0.008*
PATS	0.834	0.047***			0.834	0.046***
HC	0.302	0.092***	1.054	0.371***	0.284	0.088***
IMP			0.441	0.220*		
FDI	0.007	0.014	-0.005	0.011	0.004	0.013
Observations	60		60		60	
F/Chi2	529.53***		4.33***		551.89***	
R2	0.96		0.48		0.97	

Coefficients and Standard Errors are given in this table.

*, **, *** : Coefficients are significant at 10 %, 5 % and 1 %.

PAT, TEA, BUSF, TEABF, TRDF, TEATF, CPI, TEAC, PATS, HC, IMP and FDI denote respectively: LN(number of patent applications filed in USPTO), total entrepreneurial activity, business freedom index, TEA*BUSF, trade feedom index, TEA*TRDF, corruption perception index, TEA*CPI, LN(stock of patents), LN(total R&D personnel per million inhabitants), LN(imports of high-tech goods) and percentage in GDP of inflows of foreign direct investments.

we choose the random effects model for these two models. The probability of the Hausman test in the second specification is less than 1% (0.0000). Therefore, we choose the fixed effects model for this specification.

In models (3.1), (3.2) and (3.3), the probabilities of the Breush-Pagan test are equal respectively to 0.1231; 0.3326 and 0.2047 which are superior than 5%. We therefore conclude that there is not a problem of heteroskedasticity for the three models.

In the first and third models the probabilities of the Wooldridge test are respectively equal to 0.0140 and 0.0069 confirming the presence of an auto-correlation error problem for these estimated models. In the second model the probability of the Wooldridge test is equal to 0.0750 which is superior than 5%. We conclude the absence of auto-correlation error problem for this model.

In the following, we present the results of the linear regressions with corrections of the auto-correlation problem in the first and third specifications. Table 5 provides the results of the three linear regression models.

In the three specifications, the Fisher/Chi2 statistic testing the joint significance of the explanatory variables is significant at 1%. This allows us to reject the null hypothesis that the regression coefficients β are zero. Therefore, our models are globally significant.

First, according to the three specifications, we clearly observe that knowledge stock, human capital and imports of high tech goods have positive and significant effects on innovation level.

We turn now to our variables of interest. In the first specification (3.1), we introduce the interaction term between total entrepreneurial activity and business freedom index. Unlike the model (1), the variable relative to TEA is now negative but not significant. BUSF has a negative sign and is not significant. The term of interaction TEABF is positive but not significant. Thus, we conclude that: 1) An increase of the business freedom has no influence on technological innovation. 2) TEA is not a determinant of innovation in emerging and developing countries even if the institutional environment is characterized by a high rate of business freedom.

In the specification (3.2), we introduce the interaction term between total entrepreneurial activity and trade freedom index. The results are similar to those of the model (1). In fact, the variable relative to TEA is negative and significant at 1%. The coefficient relative to the trade freedom index is negative and not significant. What is most important in this specification is that the combined effect of entrepreneurship and trade freedom is as expected positive and significant at 1% threshold. The coefficient relative to the variable TEATF implies that an increase of total entrepreneurial activity by 1% raises the level of international patenting more in countries with higher trade freedom than in countries with lower trade freedom by 0.004%. Findings show that entrepreneurial activity is detrimental to innovative capacity of emerging and developing countries. Trade freedom has no influence on innovation level of these group of countries. However, the combination of the two factors has a positive impact. Unlike Zhu and Zhu

(2017), we don't confirm a direct positive effect of trade freedom on innovation level but we confirm its positive indirect effect through its effect on entrepreneurship. As highlighted by Baumol (1990), our results confirm the complementarity between entrepreneurship and institutions. Entrepreneurial activity is advantageous only if trade freedom index takes high values. This means that entrepreneurs have no incentives or abilities to innovate unless if their economy is open to foreign trade of goods in order to interact freely as buyers and sellers in the international marketplace. In the specification (3.3), we introduce the interaction term between total entrepreneurial activity and corruption perception index.

Findings show that the variable relative to total entrepreneurial activity is negative and significant at 5% threshold. The coefficient relative to the corruption perception index is negative and not significant. However, the combined effect of entrepreneurship and control of corruption is as expected positive and significant at 10%. The coefficient relative to the variable TEAC implies that an increase of total entrepreneurial activity by 1% raises the level of international patenting more in countries with higher control of corruption than in countries with lower control of corruption by 0.013%. Like in the last specification highlighting the key role of institutions, this finding suggests that entrepreneurial activity is harmful to technological innovation in emerging and developing countries unless if governments are able to limit corrupt practices among public agents. It is coherent with the sanding the wheels hypothesis.

In summary, the results of the model (3) are coherent with the arguments of Baumol (1990). Thus, we validate our third research hypothesis H3 according to which the effect of entrepreneurship on innovation level depends on institutions, i.e., entrepreneurs innovate in countries with high quality institutions.

Conclusion

The purpose of the present paper was to assess the effect of entrepreneurial activity on technological innovation in emerging and developing countries. Analysis of theoretical issues and previous empirical studies allows us to formulate three hypotheses: 1) Entrepreneurship affects significantly (positively or negatively) the level of innovation, 2) Opportunity driven entrepreneurschip has a positive and significant impact on technological innovation, and 3) The effect of entrepreneurship on technological innovation depends on institutions'quality. Using linear regressions on panel data, we confirm the three hypotheses. Our findings suggest that entrepreneurial activity decreases the innovation level of emerging and developing countries. They also suggest that entrepreneurs based on opportunities are able to generate innovations. In addition, entrepreneurs domiciled in a country with less corruption and less tariff barriers in international trade are associated with more innovative activities.

Our study contributes to the already substantial body of innovation and entrepreneurship literature. Its main originality is to examine the interaction that may exist between these two concepts, an issue that is neglected in previous studies. It has important implications, especially on political level. In fact, in order to stimulate innovation, policy makers may want to attract better - and not more - entrepreneurs. Moreover, they may want to examine the level of economic freedom in particular the reduction of trade barriers and the degree of control of corruption as a prerequisite for innovation policy.

Our analysis suffers however from some weaknesses. For example, the use of USPTO data imposes restrictions on the scope of our research. In fact, the innovations recorded in the USPTO are international in character, excluding local innovations which are so important in developing countries. In addition, lack of adequate data does not permit to use the Generalised Method of Moments (GMM) which allows to deal with omitted dynamics in static panel data models, owing to the ignorance of the impacts of lagged values of the dependent variable.

For further analyses, we propose new avenues. One possibility is to use other measures for technological innovation and compare the results with those found in the present paper. A second way is to make a distinction between different types of sectors (traditional vs high tech) in order to examine whether the impact of entrepreneurship on innovation is different for these different sectors.

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Endnotes

I. In this paper, we adopt the ranking of countries according to the report of the International Monetary Fund (IMF, 2012), which classifies countries into two categories: "Advanced Economies" and "Emerging and Developing Economies". Countries included in our sample are: Argentina, Brazil, Chile, Croatia, Ecuador, Guatemala, Hungary, Latvia, Macedonia, Malaysia, Panama, Romania, Russia, South Africa, Tunisia.

II. The period for granting a patent to the applicant to the USPTO is on average three years.

III. Class 7 includes machinery and transport equipment. Class 86 includes instruments (optical, medical and photographic), watches and clocks. Class 89 includes miscellaneous manufactured goods.