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Tertiary education and science as drivers of high-technology exporting firms growth in developing countries

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Abstract

In nearly all the Latin American-developing countries (LA-DC), entrepreneurial activity overseas is based on export commodities, mainly on mining and agriculture. Therefore, a shift of the entrepreneurial model-commodities-based toward high-technology represents a considerable challenge for both businesspersons and policymakers. In this sense, from an environment-industry perspective, we investigated whether a country's tertiary education and science might be drivers of the high-technology exporting firms (HTEF) growth. Furthermore, considering that most of the current studies are focused on the firm-level, by contrast, our research was conducted at a country-level. Thus, we develop a ten-year panel dataset for ten LA-DC. Through an econometric model-OLS, we provide empirical support for our hypothesis. Our results reveal that a country's tertiary education and science both together are drivers of the HTEF growth. Therefore, our conclusions will have implications at both a policy and a practical level.

Keywords High-technology exporting firms · Education · Science · Developing countries · Latin America

JEL Classification F13 · L6 · M16 · O24 · R3 · N86

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1 Introduction

In the last decade, thanks to the favorable international economic environment and booming commodities exports, some Latin American-developing countries (LA-DC) and more specifically those of South America (SA), have enjoyed high rates of economic growth which has allowed them to develop initiatives to boost their science and education systems. Firstly, by developing science and technology parks to attract and engage national talent trained abroad-reverse the brain drain. Secondly, in order to increase the growth of its high-tech entrepreneurial sector, LA-DC has focused on improving the national industry's capabilities through the absorption of knowledge from universities and technical institutes.

However, because of a lack empirical evidence identifying a well-established scientific infrastructure or more investment in tertiary education can help to high-technology exporting firms (HTEF) growth, academics, policymakers and businesspeople from developing economies do not always clearly understand how these kinds of economic and industrial policies can influence the high-tech entrepreneurship.

In the context of advanced economies empirical evidence has shown that science has a positive influence on economic growth (Bodas Freitas et al. 2013; Guerrero et al. 2015), innovative activity (Jong and Slavova 2014; Mok and Kan 2013), firms competitiveness (Audretsch et al. 2011; Barge-Gil and Modrego 2009), and on new product development and technology (Kafouros et al. 2015; Liyanage and Mitchell 1994). In the same context, different studies have revealed the positive effects that tertiary education has on economic development (Blanchard and Olney 2017; Siddiqui and Rehman 2017; Teixeira and Queirós 2016) and labor productivity (Benos and Karagiannis 2016; Lam and Liu 2011). In particular, those studies have indicated that specialization of human capital, that is to say, people with a higher level of education (tertiary education) contributes to a country's development in term of job quality, and it might help to reduce inequalities of nations (Blanchard and Olney 2017; Furukawa et al. 2012; Siddiqui and Rehman 2017) and also contribute to the development of domestic entrepreneurship (Jiménez et al. 2015).

However, the main problem the empirical literature mentioned above described highlights is the fact that most of these studies been applied exclusively in and for developed nations. Furthermore, the vast majority of them have paid insufficient attention to the role science and education might have on HTEF growth. As Castro-Gonzáles et al. (2016) warned, this kind of scientific contribution (e.g., research from developed nations) does not always have the same impact and results when it is applied to different contexts (e.g., developing nations). Likewise, Kafouros et al. (2015) state that, because developing nations' institutional environment is underdeveloped, this puts them at a significant disadvantage regarding developed economies. For instance, Peña-Vinces et al. (2017) find that in LA-DC, the political and business environments are chaotic. This political instability (e.g., high-interest rates, fuel prices, corruption, etc.) causes frequent changes to the regulatory framework producing disastrous consequences for these countries' domestic economies and consequently for HTEF growth, which operated from those nations, LA-DC.

In the context of LA-DC, no studies have been published focusing on high-technology exporting firm growth, at least to the knowledge of authors. However, a study on Peruvian exporting SMEs by Peña-Vinces and Urbano (2014) found that role played by university-research centers does not have a positive effect on SME competitiveness. However, we must point out that such a study analyzed only exporting firms but not on HTEF. Thus, this *research gap* suggests the great need to conduct this research. Therefore, our research objective is to answer the following question: *Are national tertiary education and science drivers of the high-technology exporting firm growth in LA-DC?* Most of the LA-DC entrepreneurial activity is based on commodities export like mining and agriculture. We, therefore, argue that tertiary education and science are drivers of HTEF growth. Theses socio-economic agents (Peña-Vinces and Urbano 2014) would be critical factors shaping the *LA-DC*'s entrepreneurial pattern that is a transformation from commodities toward high-tech.

Employing a ten-year panel dataset from ten *LA-DC*, and through an OLS econometric model, our results suggest that an increase in *LA-DC* investment in tertiary education will enhance HTEF growth. Likewise, if Latin American enterprises wish to become high-tech global exporters, they must have access to a pool of potential employees with highly developed technical and scientific skills. Hence, our results show that a country's science has a positive impact on HTEF growth.

Finally, our study provides findings for both professionals and scholars and could contribute to planning public policy, particularly for *LA-DC*, whose governments are sometimes not even aware of how investments in education and science could impact entrepreneurial activity, such as HTEF growth.

This paper has five sections. In Sect. 2, we review the literature, which led to the formulating of our research hypotheses. Section 3 is dedicated to the methodology. Section 4 deals with empirical and statistical analyses and presents the results. In Sect. 5, we conclude with a brief discussion of policy options.

2 Conceptual framework and hypotheses

The institutional theory establishes that some national institutions might either constrain or alternatively, enable firm growth (Audretsch et al. 2011; Krasniqi and Desai 2016; Urbano and Alvarez 2014). In our case, institutions with a mandate for education and science might constrain the growth of HTEF. Thus, if firms do not rely on skilled labor, they might have a severe problem compete in global markets (Barge-Gil and Modrego 2009; Czinkota and Pinkwart 2012). Likewise, if patents developed by universities do not have commercial potential (Leten et al. 2014); consequently, high technology firms would not exploit them. These are just some examples of how the institutional environment might constrain HTEF growth.

Alongside institutional theory, the environment perspective shows that the success of firms across borders is at least partially determined by the conditions of their country of origin (Coviello et al. 1998; Mesquita et al. 2013; Peña-Vinces et al. 2017). In this sense, education and science may play a fundamental role in HTEF growth. In our case, we focused on tertiary education because people with higher education are usually active in the formal labor market (Peña-Vinces 2009; Whittemore 1998). As the World Bank (2002) affirms, tertiary education (workforce with advanced studies) directly influences national productivity, which in its turn affects living standards and a country's ability to compete globally. In the domain of science, we focused on developing country scientific outputs and the effects on HTEF growth.

Apart from the two theories mentioned before, the industrial development perspective is fruitful in explaining HTEF growth. Businesses growth overseas largely depends on domestic market success (Cho et al. 2008; Choo and Moon 2000; Solucis

Santhapparaj et al. 2006). In other words, from success within national boundaries. Thus, companies located in countries with highly competitive educational and scientific systems tend to benefit from the spillover effect (Mok and Kan 2013; Yaşar and Paul 2011). This is the reason why some firms tend to gravitate toward countries where the educational and scientific levels are recognized worldwide (Leten et al. 2014).

2.1 A county's tertiary education

Tertiary education (TE), commonly known as post-secondary education, is also called advanced studies. In our research, we focused on analyzing how TE is important to both enterprises and countries. One key reason is that TE supports the rest of the educational system (Heyneman 2001; Whittemore 1998). TE contributes to the preparation of teachers and school principals and includes the establishment of admissions conditions influencing the curriculum, teaching, and learning methods at the secondary level (The World Bank, 2002). TE not only enhances the training of medical doctors, engineers and business people but also the training of specialists across a wide range of other areas (Leten et al. 2014; Newman 2014). TE is also shaped by government policies towards education (Benos and Karagiannis 2016). TE is a powerful instrument of human development and national economic prosperity (Blanchard and Olney 2017; Furukawa et al. 2012; Siddiqui and Rehman 2017). Considering TE adds skills to labor, firms will have greater access to highly skilled labor and human capital (Benos and Karagiannis 2016; Czinkota and Pinkwart 2012).

Newman (2014) has argued that national governments must guarantee access to TE as it can be a door to better employment and income opportunities for underprivileged students and thus can reduce social inequalities. Education in developing countries also provides access to migration opportunities, affording the chance to move abroad to seek work (Czinkota and Pinkwart 2012; Siddiqui and Rehman 2017).

Education is a critical vehicle for achieving economic progress. Education, and notably TE, is a cornerstone of a country's development, both economically and industrially (Benos and Karagiannis 2016; Teixeira and Tavares-Lehmann 2014). Enterprises might count on qualified workers to allow them to be able to compete overseas (An and Iyigun 2004; Benos and Karagiannis 2016; Blanchard and Olney 2017). An excellent educational system provides highly skilled and qualified human resources (Benos and Karagiannis 2016; Czinkota and Pinkwart 2012; Tzeng 2011), who will eventually manage and lead companies toward investing in foreign markets (Kafouros et al. 2015; Mok and Kan 2013).

Heyneman (2001) argues that if a country's goal is to promote entrepreneurial activity overseas, it must offer joint degree programs between educational institutions and industry. Moreover, in a similar vein, Lam and Liu (2011) show that countries that have implemented policies to expand access to higher education and have ensured rapid growth in university enrolment have experienced an increase in exporting activities, as in the case of Hong Kong. This is because operating in foreign markets is confronted by a variety of barriers—cultural, linguistic, logistical, political, etc.—and a well-prepared and trained labor force could transform these into opportunities (Czinkota and Pinkwart 2012; Guan and Ma 2003; Teixeira and Tavares-Lehmann 2014). It is important to recognize that when the countries entrepreneurial activity across borders increases, their firms are also likely to grow, and this will have a positive effect on national employment because firms will be more able to employ a larger workforce (Blanchard and Olney 2017).

The globalization of superior education enhances the competitiveness of educational institutions and knowledge transfer that goes beyond national boundaries (Czinkota and

Pinkwart 2012; Furukawa et al. 2012). Skills-intensive manufacturers grow as the economy shifts towards high value-added manufacturing, generating an increased number of highly skilled jobs (An and Iyigun 2004; Kafouros et al. 2015; Lam and Liu 2011).

An and Iyigun (2004) analyzed data from 86 countries and found that countries with higher secondary enrolment exhibit higher rates of economic growth. Furukawa et al. (2012), based on a study carried out with a sample of 7000 people with post-secondary education (i.e., Bachelor, Master, and Ph.D.), demonstrate that there is a clear relationship between the educational background of workers and the growth of the high-tech industry.

Moreover, a good education system could encourage more workforce mobility between countries (Furukawa et al. 2012; Mok and Kan 2013) which will eventually benefit firms that need highly skilled labor (An and Iyigun 2004; Lam and Liu 2011). Furthermore, a well-educated population will be able to change local communities and will help the development of their nations (Benos and Karagiannis 2016; Lam and Liu 2011). Teixeira and Tavares-Lehmann (2014) have found that training and education as an investment in labor must consider knowledge and capabilities required by the "progressive" industries controlling the economy, namely those that involve increases in productivity and accelerate economic growth.

Heyneman (2001) suggests that countries should provide not only formal education but also other types of training, such as corporate training and knowledge dissemination through technology-based education. Of the three, corporate training has the most positive effect on entrepreneurial activity overseas.

Higher skill levels in the labor force (Siddiqui and Rehman 2017)– a result of increased TE—and qualitative improvements by permitting workers to use new technology, similarly increase productivity (Benos and Karagiannis 2016; The World Bank 2002). In similar research, Mok and Kan (2013) have also shown that education is essential for achieving the internationalization of national production; however, they argue that to increase economic growth, entrepreneurship education is critical, as has been the case in China.

Therefore, from the above, and in the context of LA-DC, we establish the following hypothesis:

Hypothesis 1 (+): A country's tertiary education is positively related to HTEF growth located in developing countries

2.2 A country' science

Our research attempt to evaluate if a country's science (CS) might be a driver of high-technology exporting firm growth. In this sense, we are focused on the capability of countries to develop science (Leten et al. 2014; Whittemore 1998). A country's science is linked to its researchers' skills and capabilities (Jong and Slavova 2014). Furthermore, science can come from different fields of knowledge, more specifically technology, medicine, engineering, business, and economics, etc. (Guerrero et al. 2015; Quintas et al. 1992). When one is studying a CS, it is also essential to address the role that universities and research centers play (Bodas Freitas et al. 2013; Guerrero et al. 2015; Héraud and Lévy 2005) as technological innovations are developed within these institutions (Leten et al. 2014; Mok and Kan 2013; Watkins et al. 2015). The dissemination of scientific and technical developments results in superior productivity, since such developments are typically the consequences of the application of either basic or applied scientific knowledge (Watkins et al. 2015; Whittemore 1998; Yaşar and Paul 2011). Similarly, universities perform a crucial role in the innovation systems of countries (Quintas et al. 1992) in two ways. Firstly, these institutions (universities) are in charge of training national human capital, which is vital for the development of research and development both for economies and firms (Peña-Vinces et al. 2019), specifically in the disciplines of science and engineering. Secondly, they manage scientific research resulting in knowledge that can be useful for businesses innovation activities (Kafouros et al. 2015; Yaşar and Paul 2011).

A review of the literature on a CS (Bodas Freitas et al. 2013; Furukawa et al. 2012; Tzeng 2011) shows that in many countries, economic progress depends significantly on scientific development and it is profoundly dependent on the exploitation of innovations. Therefore, a good innovation system should help build considerable economic progress (Watkins et al. 2015; Yaşar and Paul 2011). However, a CS does not develop by itself; it is necessary to have highly trained human resources, in other words, high-quality researchers/scientists (Bodas Freitas et al. 2013; Tzeng 2011). A country with a good science system induces not only economic growth but also attracts human capital from other regions (Furukawa et al. 2012; Lam and Liu 2011). Similarly, Guerrero et al. (2015) argued that science has an impact on the economic development of nations when domestic universities can generating, attracting, and retaining prestigious researchers/scientists.

Empirical evidence shows that those countries that have clear policies for fostering science have become global exporters (Kafouros et al. 2015; Liyanage and Mitchell 1994). China, for example, is a country characterized by well-designed science and technology parks, which have enabled it to become one of the leading high-tech exporters in the world (Guan and Ma 2003; Mok and Kan 2013). However, the case of China is not exceptional; numerous other examples exist (e.g., Liyanage and Mitchell 1994 in Australia, Dufour and Gingras 1988, in Canada Jong and Slavova 2014).

Usually, governments provide funding and regulatory frameworks for innovative companies, whereas science institutions promote new ideas and expertise which allow the consolidation of R&D departments of high-tech industries which then could become large science tech parks (Quintas et al. 1992; Watkins et al. 2015).

A CS brings benefits enterprises in terms of knowledge accumulation and application and thus becomes an essential factor for economic development and the country's competitive advantage (Bodas Freitas et al. 2013; Jong and Slavova 2014). Therefore, scientific institutions and enterprises can be integrated to a considerable advantage (Bodas Freitas et al. 2013; Czinkota and Pinkwart 2012; Whittemore 1998). Their work can then be translated into high-quality products with higher export potential (Guan and Ma 2003; Mok and Kan 2013). However, we are aware that knowledge does not in itself transform nations and firms, but that well-trained human capital is also necessary to achieve this goal (Mok and Kan 2013; Tzeng 2011; Yaşar and Paul 2011). Hence, nations must have a significant number of scientists engaged in research and technological development (Leten et al. 2014; Peña-Vinces et al. 2019). It is broadly recognized that knowledge is a critical factor in economic growth (Guerrero et al. 2015) and that this is transformed into goods and services by domestic firms that are active in the international market (Bodas Freitas et al. 2013). In this regard, Heyneman (2001) emphasizes that to attain this (knowledge), it is necessary for researchers to have the technical and theoretical knowledge, which requires people with both academic and industrial experience.

Regarding SC and its direct effect on the entrepreneurial activity (Audretsch et al. 2011; Bodas Freitas et al. 2013; Mok and Kan 2013) it is usually assessed in terms of knowledge transfer, through new products and processes or by means of various channels, among them patenting and the licensing of inventions (Kafouros et al. 2015; Yaşar and Paul 2011), new ventures and university-industry alliances (Bodas Freitas et al. 2013; Czinkota and

Pinkwart 2012; Jong and Slavova 2014). Nonetheless, not all companies benefit from the advance of science in domestic institutions (Bodas Freitas et al. 2013; Leten et al. 2014). Empirical research (Barge-Gil and Modrego 2009) has determined that small enterprises (SE) have limited scope to assimilate the knowledge belonging to these types of institutions and, as a consequence, find it challenging to reap the full benefit of them. Likewise, SE is not conscious of the knowledge created by scientific organizations, that in itself hinders them from attaining a competitive advantage (Czinkota and Pinkwart 2012). Other academics (Barge-Gil and Modrego 2009; Heyneman 2001) have also claimed that scientific organizations are more productive in their outcomes when the state supplies economic funding for their research projects.

As Watkins et al. (2015) identified, examples of scientific and technological knowledge in developing countries are few and far between when compared to more advanced regions. Therefore, we propose the following hypothesis:

Hypothesis 2(+): A country's science is positively related to HTEF growth located in developing countries

3 Data and methodology

3.1 Variables of the research model

3.1.1 Dependent variable

Measuring firm growth has been controversial since there does not exist one standardized indicator (Bravo-Biosca et al. 2016; Krasniqi and Desai 2016). However, Krasniqi and Desai (2016: 1081) established that, if researchers wish to measure it, they must be sure to measure both business changes, such as changes in sales, employment, etc. In our case, our measure of firm growth is based on the change in international sales of high-technology products, that is firm exports.

High-technology exporting firms at a country-level is usually measured by using high-tech exports as a percentage of total manufactured exports. In fact, Alvarez and Marin (2013) have used this indicator as a function of Multinational Enterprises (ME) competitiveness. These researchers established that such a variable could capture the firm's ability to compete and survive abroad over time. However, in our research (at a country-level), we need to measure the growth of high-technology exporting firms rather than their international competitiveness. Therefore, we need a measure to reflect long term growth. Thus, we took as a departure point a measure which is commonly used, GDP per capita (An and Iyigun 2004; Krasniqi and Desai 2016).

Based on Alvarez and Marin (2013), high-tech exports per capita are used to measure high-technology exporting firm growth. This measure reflects both the growth of international sales and its changes over ten years:

$$\text{HTEF}_{\text{growth\_}}\text{X} = f\left(\text{high - tech exports per capita}_{10\_\text{countries}\_2008-2017}\right)$$

3.1.2 Independent variables

The goal of this paper is to analyze how education policy contributes to high-technology exporting firm growth in developing countries. Thus, two measures were necessary to assess this variable. Firstly, we used public education spending on tertiary education as a share (%) of government expenditure on education. The World Bank (2002) suggests it is impossible to analyze the effect of education on the domestic economies without including public spending on education, given that this macroeconomic factor (education) is a driver of national economic progress. Secondly, we used the percentage of the working labor force having attained advanced education (Benos and Karagiannis 2016). In the entrepreneurial context, this indicator would reflect if skilled personal (Lam and Liu 2011; Leten et al. 2014) working in companies in developing countries might facilitate firms to gain technological capabilities (high tech production). As we mentioned, in most of the developing countries, entrepreneurial activity at an international level is based on commodities.

To measure the level of science in a country, the number of researchers, along with their output, is used (Watkins et al. 2015; Yaşar and Paul 2011). This variable also enables us to determine whether domestic science helps national firms to attain more success abroad (high-technology exporting). In the context of developing economies, Peña-Vinces et al. (2019) have operationalized this construct; thus, following their research, we used the same indicators (see them in Table 1).

3.1.3 Control variables

High-technology exporting firms growth might be influenced by multiple factors beyond TE and CS. Therefore, three control variables were used. The first was the GDP growth because nations which have high rates of economic growth tend to support and promote their export companies (Malca et al. 2019; Mok and Kan 2013; Watkins et al. 2015). The second control variable is the inverse of the tax burden on firms (1-taxes). Peña-Vinces (2009) emphasizes that if a country relieves some of the corporate tax burdens, i.e., imposing fewer taxes for exporting companies, foreign operations will increase. The last control variable is value added-services since the presence of service firms enables other firms to outsource some of their key activities like logistics and ICT (Mesquita et al. 2013; Peña-Vinces et al. 2012). Thus, firm success abroad depends on home-industry cooperation (Peña-Vinces and Urbano 2014; Solucis Santhapparaj et al. 2006).

Table 1 provides a summary of the measures used for each variable along with the time period and sources of data.

3.2 Data description

As mentioned above, our study is at the country-level rather than the firm-level. By using data from The World Bank, United Nations, UNESCO, and others (see Table 1), we built a ten-year a panel dataset for the period 2008 to 2017, which was the final year with public information available. Thus, our sample was composed of 10 countries and ten years, which account for *a total of 100 observations.*

Figure 1 shows the countries included. Nearly all of the economies of South America are included in the analysis, with only Guyana and Suriname being excluded due to the lack of available information.

Table 1 Variable/indicators, definitions, and source

Control variables (2008–2017)	Definition	Source
Science (2008–2017)		
Articles published	Refer to the number of scientific and engineering articles published during the period of study	National Science Foundation, Science and Engineering Indicators.
R&D	Research and development expenditure (% of GDP)	UNESCO Institute for Statistics
Researchers	Researchers working in R&D (per million people)	UNESCO Institute for Statistics
Patents	Patent applications, residents	World Intellectual Property Organization
Tertiary education (2008–2017)		
Expenditure on education	Expenditure on tertiary as a percentage of government expenditure on education (%)	UNESCO Institute for Statistics
Workforce with advanced education	Labour force with advanced education (% of the total working-age population with advanced training)	International Labour Organization, ILOSTAT database
High-technology exporting firms' growth (2008–2017)		
High-technology	High-technology exports per capita (in American dollars). It refers to exports of products with a high R&D component	UN Comtrade
Control variables (2008–2017)		
Economic growth	GDP per capita (in American dollars)	The World Bank
Fiscal pressure	1- Taxes on goods and services (% of revenue)	The World Bank
Services	Services, etc., value added (% GDP)	The World Bank

Note At the appendix, we present a Table which summaries the descriptive statistics of our variables

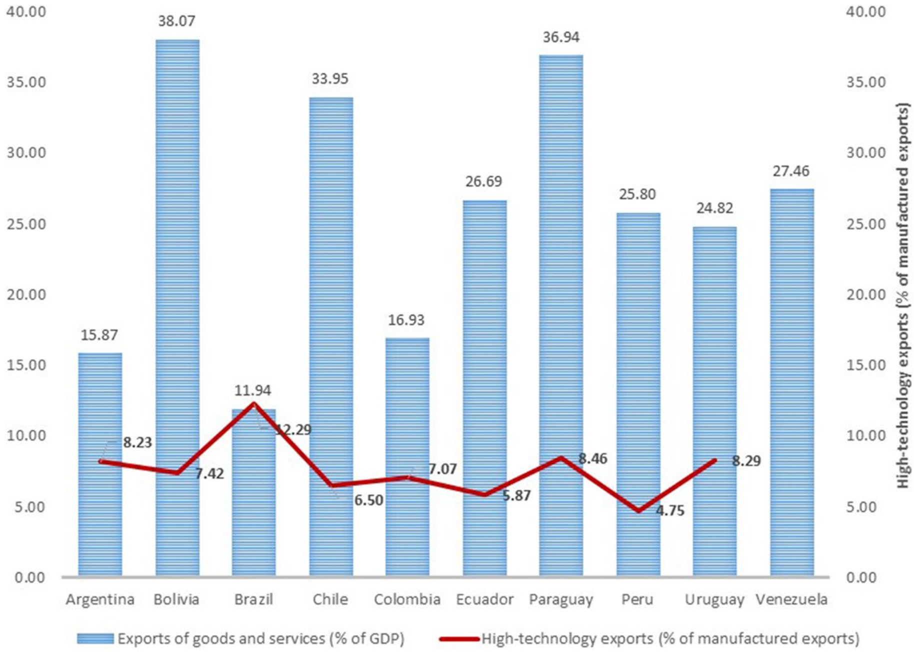

Fig. 1 Exports of developing economies vs. high tech exports (2008–2017). *Source*: Own using data from United Nation Comtrade

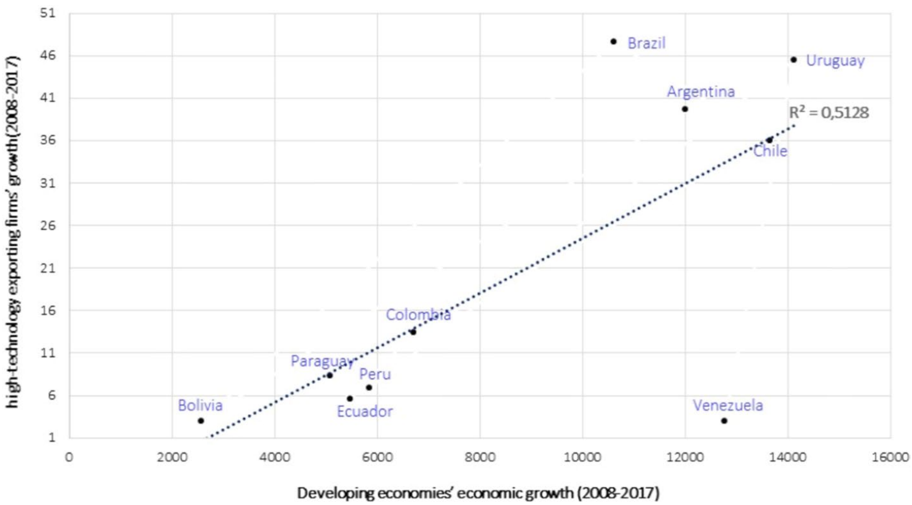

Fig. 2 Economic growth vs. high-technology exporting firms growth (2008–2017). *Source*: Own using data from the United Nation Comtrade and the World Bank

Moreover, and before moving to the econometric analysis, we believe that it is crucial to provide a descriptive analysis of the data and measures used in the analyses, in order to better understand the institutional and economic contexts from which enterprises based in

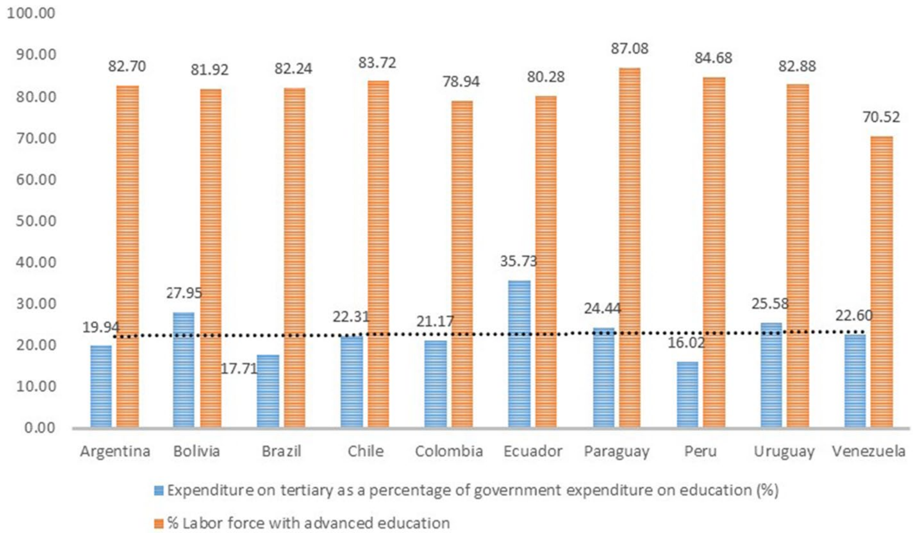

Fig. 3 Expenditure on education vs. workforce with advanced education (2008–2017). *Source*: Own using data from UNESCO and ILOSTAT

LA-DC operate overseas. Figure 1 shows that most of the LA-DC enterprises operate in the domestic market (75%) and just 25% operate in foreign markets (exports of goods and services). Furthermore, most of the products they sell abroad (exports) are based on traditional exports, mainly mining and agriculture. In addition, as the red line depicts, over the entire time period an average of just 8% are accounted for by high-tech export enterprises. This is a low share of high-tech export enterprises, when compared to 17 percent in both Germany and Japan, is 17%, and 19 percent in the United States.

Figure 2 also shows that high-technology exporting firm growth was pretty unequal. In fact, there were two groups of firms—high growth and low growth. The high growth group includes companies in Brazil, Argentina, Chile, and Uruguay. The low growth group includes companies in Colombia, Peru, and Ecuador, among others. In addition, this figure also indicates that the country's economic growth is associated with enterprise growth. This confirms the importance of including country growth as a control variable when explaining firm growth. In addition, firms located in countries with greater economic growth tend to receive more support from their governments. As a result, they exhibit a stronger export performance than do their counterparts located in low-growth countries (Fig. 2).

Figure 3 shows how the share of education expenditures accounted for by tertiary education varies across countries. In particular, Ecuador and Bolivia exhibit the highest share of education allocated towards tertiary education. In addition, Fig. 3 shows that the share of the workforce with a tertiary education does not vary greatly across South American countries.

Figure 4 compares innovative activity across South American countries, measured in terms of researchers devoted to R&D, patents, and the share of GDP accounted for by R&D. Brazil and Argentina are clearly the most innovative countries in South America. By contrast, Peru and Paraguay exhibit only meager levels of innovative activity.

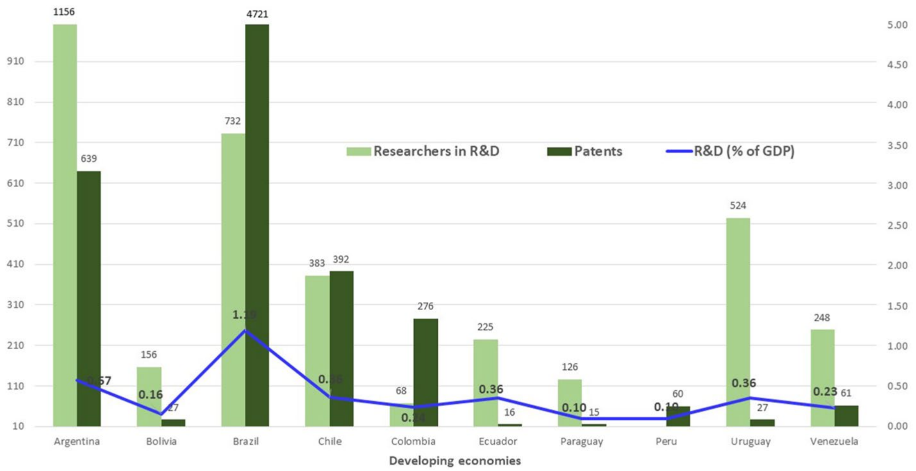

Fig. 4 Developing countries' science (2008–2017). *Source*: Own using data from the National Science Foundation, UNESCO and World Intellectual Property Organization

4 Econometric model and results

4.1 Econometric model

To test the hypotheses that tertiary education and science are positively related to high-technology exporting firm growth, an OLS model was estimated. To do so, we have employed the IBM's SPSS V. 22 software. Therefore, our econometric model to be estimated is the following:

$$\begin{aligned} HTEF_{cij\_2008-17} = a_1 &+ \beta_1(Education_{cij\_2008-17}) \\ &+ \beta_2(Science_{cij\_2008-17}) + \beta_3(Economic\,growth_{\_2008-17}) \\ &+ \beta_4(Services_{cij\_2008-13}) + \beta_5(Fiscal\,pressure_{cij\_2008-17}) + \varepsilon_1 \end{aligned}$$

where *HTEF = High-technology exporting firms growth,* $a_{1= Intercept}$, *cij = represent the LA-DC studied;* ε *= residual term.*

Our econometric model was composed of five variables, of which two of them are latent (TE and SC), and the rest are observable variables. When working with the latent variables using secondary data, it is considered crucial to evaluate its validity and reliability (Peña-Vinces et al. 2019). This indicates if a construct-variable adequately measures the concept in question. In this sense, and before moving forward, it is important to undertake the validity and reliability analyses. First, we had to impute the missing data from our data panel. As is the standard practice case for using secondary sources, this procedure is considered normal (Almeida et al. 2017; García-Sánchez et al. 2015).

Table 2 EFA and variables validity and reliability

Variables/indicators	λ	λ^2	KMO	χ2	AVE	CA
Science			0.69	614.695***	0.782	0.964
Z_Researchers	0.588	0.346				
Z_Articles published	0.962	0.926				
Z_RyD	0.976	0.953				
Z_Patent	0.951	0.905				
Tertiary Education						
Z_ Expenditure	0.742	0.551	0.500	3.685*	0.510	0.852
Z_Workforce	0.742	0.551				
Recommended						
Values	0.40	0.20	0.50	≤0.10(*;**;***)	≥0.50	≥0.70

Nevertheless, Hair et al. (2010:50) have established that this procedure only must be applied when the set of missing data does not exceed 20.0%[1] of the aggregate data. In our case, the missing data is below the maximum permitted. There are a number of different ways of how to address such a matter (Almeida et al. 2017). However, the software employed might condition enormously the particular way implemented. In our case, as is recommended by Hair et al. (2010), our data were imputed using the method of the linear regression-SPSS algorithm- known as a fully conditional specification (Z). Second, we standardized the variables. This procedure is recommended when a panel data present a different unity of measurement (Almeida et al. 2017; Peña-Vinces et al. 2019). In our case, the panel data was composed of percentages, currencies, figures, and so forth. The main advantage of the standardization of indicators is that they are normally distributed (Almeida et al. 2017; García-Sánchez et al. 2015) or at least symmetrically distributed. Therefore, using the SPSS's tool for the standardization of variables, we computed the Z-scores, which reproduce robust results from the original variables (Hair et al. 2010).

Then, by using an exploratory factorial analysis (EFA) with a varimax rotation, we evaluated the validity and reliability of latent variables (TE and SC). Table 2 shows the values obtained from this analysis. Thus, individual item reliability estimation was evaluated through standardized loadings (λ), which showed that their values exceed the threshold (Hair et al. 2009; Peña-Vinces et al. 2019). The reliability of the latent variables, according to the Cronbach alphas (CA) and average variance extracted (AVE) exceed the limit set (Hair et al. 2009; Peña-Vinces et al. 2019)

Loadings (λ); Communalities (λ^2) Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity (χ2)).

Once we evaluated the validity and reliability of the latent variables, we next proceeded to run our OLS. Table 3 presents the results of OLS estimation. The normality of

[1] Unfortunately, there are no consensuses between researchers about the limited accepted to impute a dataset. For instance, Hair et al. (2010:50) have established a limited of 20%, and it might be extended more depending on the sample size. However, García-Sánchez et al. (2015) argument that it must not above 15% of the entire data. In our case, it accounts for 17% of aggregate data; therefore, our missing data it is in the average of these figures.

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Table 3 OLS results

Variables		Model 1	Model 2	Model 3	Model 4
Tertiary education		−0.042	0.126		0.149
		(0.101)	(0.080)*		(0.047)***
Science			0.668	0.300	0.385
			(0.080)***	(0.063)***	(0.058)***
Economic growth				0.545	0.555
				(0.057)***	(0.055)***
Services				0.257	0.227
				(0.066)***	(0.064)***
Fiscal pressure				−0.050	−0.050
				(0.055)	(0.053)
Education*science				−0.053	
				(0.059)	
Constant_HTEF		−6.960	−6.960	−0.015	−3.184
		(0.100)***	(0.077)***	(0.048)	(0.043)***
ANOVA	F	0.170	35.201***	78.077***	87.375***
	df	1	2	5	5
R		0.042	0.649	0.898	0.907
R^2		0.002	0.421	0.806	0.823
Adjusted R^2		0.008	0.409	0.796	0.814
Std. Error of the Estimate		1.004	0.769	0.452	0.431
Change R^2		0.002	0.421	0.806	0.823
Endogeneity test H_0: Durbin Watson		2.319	2.143	1.960	1.920
N		100	100	100	100

Notes * 10% significant; *** 1% significant; standard errors are in parenthesis

the error terms was estimated by using the probability plots of residuals, which revealed that there were no substantial deviations of values from the diagonal line. Simultaneously, we evaluated the intensity of the relationship between the dependent variables and their predictors by examining the partial correlations (pc). This analysis reveals a stronger relationship with science (pc = 0.562) than with tertiary education (pc = 0.312). Similarly, the strongest relationship between HTEF growth and the control variables is with economic growth (pc = 0.723). Likewise, we evaluated the multicollinearity (Hair et al. 2009) of our independent-predictors variables. This assessment revealed that none of the predictors had problems since the values reported never were below the limit set (VIF ≤ 5.0). In fact, the values were the highest for the variable services (FIV = 2.141), and the values for the rest of the variables never exceeded 2.00 (see Appendix A). Finally, it is important to point out that the OLS endogeneity was evaluated by using the Durbin Watson's test, which revealed satisfactory values (see Table 4).

4.2 Results

Table 4 summaries results from the OLS estimation. First, Model 1 shows that when we used exclusively tertiary education as a predictor of HTEF growth, the results are not significant ($\beta = -0.042$). However, Model 2, which includes both science and tertiary education as predictors of HTEF growth did display positive results (Education; β=0.126*). In the context of developing economies (e.g., LA-DC), those results indicate that tertiary education solo works as a driver of HTEF growth when it jointed to science and never by itself. On the base of these findings, Model 3 attempts to explore if tertiary education might be a moderator of the relationship between science and HTEF growth. However, the results were not significant (β=− 0.053).

Moreover, HEFT might depend on multiple factors and not only on education and science (Model 2). Thus, consequently, a more realistic model will be able to calculate the real weight that science and education have on HTEF growth. Therefore, in Model 3, we included economic growth, services, and taxes as control variables. The results show that besides adding control variables, science and tertiary education remain positively related to HTEF growth. In fact, this model produces an increase of 48,85% the R^2 compared to the model without the control variables (Model 2). Likewise, it is remarkable to observe the high quality predicted (Model 4), which is nearly close to 1 (R). This figure is pretty surprising as it is unusual in economic and business studies.

Having provided general results, the focus is now placed on the two hypotheses. To do so, we must pay attention to Model 4. This model suggests that both tertiary education and science play a fundamental role as drivers of HTEF growth. Therefore, our results are consistent with previous empirical research by An and Iyigun (2004), which revealed that those countries with higher rates of secondary enrolment tend to exhibit a stronger export potential. Likewise, the results are consistent with the findings by Furukawa et al. (2012), who analyzed the relationship between educational background and high-tech industry intensity, as well as those of Heyneman (2001), who found that the OECD regions that invest more in education enjoy higher rates of economic growth. Thus, we support hypothesis $\mathbf{H_1}$ (ß = 0.149, $p < 0.01$) indicating that training people (tertiary education) not only would provide benefits for high-technology exporting firms growth but also for the whole educational system (Heyneman 2001; Whittemore 1998) as TE might help countries to improve their industrial and scientific capabilities (Peña-Vinces et al. 2019) by increasing the proportion (%) of the labor force accounted for by of qualified workers.

The empirical evidence also supports the second hypothesis ($\mathbf{H_2}$), based on the values of the coefficients (ß = 0.385, $p < 0.01$) of Model 4. In addition, science is relatively more important in influencing HTEF growth than is TE. Thus, the results are also consistent with the previous literature in that a strong national science system will contribute to a stronger performance exhibited by the domestic industry abroad (Czinkota and Pinkwart 2012; Dufour and Gingras 1988; Mok and Kan 2013). In other words, a strong national system contributes to the high-technology exporting firms growth. This means that despite the limited scientific capacity of LA-DC, it is helping to create high-tech products which then must compete worldwide. In the same vein, a country's science not only provides the transfer of knowledge in the form of patents (for example), but also enables national enterprises to incorporate well-trained personal (researchers). Finally, with respect to the control variables (Model 4), the results suggest that both economic growth (ß = 0.555, $p < 0.01$) and services (ß = 0. 227, $p < 0.01$) condition HTEF growth. The results are consistent with Alvarez and Marin (2013). They showed the importance that supply chains have for the competitiveness of international firms. In our case, national suppliers would be necessary for how companies can manufacture their high-tech products.

5 Conclusions and implications

5.1 Concluding remarks

This paper has attempted to link high-technology exporting firm growth to country-level economic conditions. Interpreting the results and drawing out implications are shaped by linking the micro to the macro. In the context of developing economies, LA-DC, we wherefore have examined whether tertiary education and science at the national level might be drivers of high-technology exporting firms growth. In addition, as mentioned in the introduction, our research should be of interest to both academics and practitioners. As decision-makers from developing economies (Casanova and Kassum 2014) need to understand how and why education and science policies might contribute to enhancing the growth of the high-technology-export sector in the context of LA-DC.

The entrepreneurial export sector is fundamentally based on commodities. Consequently, a country's high-technology entrepreneurial sector plays a crucial role since it might help economies to be less dependent on commodities and much more competitive globally (Castro-Gonzáles et al. 2016; Peña-Vinces et al. 2019). However, we should not forget that states do not transform economies, but that entrepreneurial sectors do (Bodas Freitas et al. 2013; Peña-Vinces et al. 2012).

On the one hand, our results suggest that government expenditures on tertiary education will help to increase HTEF growth. Thus, long-term investment in tertiary education has a positive effect on HTEF growth (Furukawa et al. 2012). Therefore, our finding suggests that the LA-DC government policies adopted over the decade have been consistent with those of the most advanced economies (Lam and Liu 2011), which view their education system as a vehicle to improve their competitiveness. South Korea is a clear example of this, which has become in one of the most innovative and competitive countries in the world. However, it is not only expenditures on tertiary education that are essential for the growth of high-technology exporting firms but also a highly trained and skilled workforce (An and Iyigun 2004; Benos and Karagiannis 2016; Lam and Liu 2011), in other words, it would be necessary that developing countries generate a labor force having attained advanced degrees. Because high-technology enterprises need highly qualified workers with high levels of human capital, it will be difficult to sustain their growth over the long term. Even more importantly, it would be more difficult if developing economies want to change the trajectory from commodities-based toward an entrepreneurial high-tech sector (Barge-Gil and Modrego 2009; Bodas Freitas et al. 2013; Teixeira and Tavares-Lehmann 2014). In fact, in the region (Latin American), most of the entrepreneurial sectors are manufactures and exporters of raw materials. In this aspect, the evidence suggests that only 7,65 percent of the total firms are accounted for by high-tech export companies. This percentage is small compared to more advanced economies (e.g., Germany, Japan, the USA, UK, etc.). We would like to posit an explanation for the relatively low share of high-tech exports in the South American context. Most of the LA-DC firms' outputs rely on imitating existing products and product assembly using components sourced outside the region, rather than the developing new products, as in the case of China. Another explanation for this fact it could be that most of the LA-DC enterprises are SMEs (Malca et al. 2019). The OECD statistics (OECD 2013) revealed that 99% of the LA-DC firms are SMEs, and only 10% are MNE. A review of the literature shows that SMEs have trouble in benefiting from national science outcomes (Czinkota and Pinkwart 2012; Tzeng 2011) because their small size means they do not have the capacity to absorb knowledge (Birru 2011; Czinkota and

Pinkwart 2012) or to hire researchers (Peña-Vinces and Urbano 2014). In this sense, Mok and Kan (2013) suggest that to address the gap between traditional and non-traditional exporting, nations must offer considerably better entrepreneurship education including on-the-job training designed to impart practical knowledge, as in the case of Germany, and in line with research carried out in China (Kafouros et al. 2015). In summary, in the region, there is much work to do, in particular, if domestic firms want to evolve from suppliers of raw materials to becoming important players by competing in international markets with high-tech products.

On the other hand, a key role needs to be played by the second driver of high-technology exporting firm growth, that is science. Professionals must show an interest in high-technology exports as a vehicle to accumulate foreign currency reserves, increase employment rates, boost national productivity and improve social prosperity– such as in the case of Brazil with its auto-parts industry (Mesquita et al. 2013). As Whittemore (1998) confirms, basic research does not always lead to useful applications; nor is there necessarily a linear progression of research through technology and development to advancement in the quality of life. This may be one of the reasons why policymakers in LA-DC allocate very few resources to the development of science. Empirical evidence shows that the high-tech sector could improve a nation's economic progress (Bodas Freitas et al. 2013; Leten et al. 2014; Tzeng 2011).

Moreover, economic history has shown that countries with traditional exporting models have not yet developed in the region, such as Bolivia and Ecuador. Nevertheless, it must not be forgotten that behind the development of high-tech products, there is considerable human capital (Jong and Slavova 2014; Mok and Kan 2013; Watkins et al. 2015). In this regard, our results show that Latin American developing nations are developing in a positive direction.

There are important implications concerning the positive of science on the high-technology exporting firm growth. The empirical evidence suggests that national expenditures on R&D have a positive impact on it (λ=0.976). In fact, compared to the other measures of innovation, R&D seems to be important for high-technology exporting firm growth (see Table 2). The results are consistent with previous studies that found a similar effect that R&D had on MNE competitiveness (Alvarez and Marin 2013) and firm innovation (Yaşar and Paul 2011). In the context of developing economies, our research contributes to the body of literature on R&D by showing the positive effect it has on HTEF growth. However, we also highlight that qualitative data indicating that most of LA-DC except for Brazil, designate less than 1% of GDP to R&D activities. This amount is slight compared to more advanced economies (e.g., Germany, Japan, and the USA). For example, Germany, a world leader in the export of high-quality products, allocated 2.92% of its GDP to R&D during 2010–2018 (The World Bank 2018). Therefore, it appears that in advanced nations, high-tech exports with an R&D component are crucial to competing abroad. LA-DC's entrepreneurial sector is principally based on the exports of raw materials, and might follow this path to become a big player of the world trade of high-tech.

Moreover, innovative activity, as measured by R&D and patents, is another element that is an essential component of science, which is positively related to HTEF growth (λ=0.951). This result is consistent with those studies which found that a country's patents contribute to productivity (Yaşar and Paul 2011) and an innovative firm capacity, as is the case of Chinese enterprises (Kafouros et al. 2015). However, its impacts would not be the same in the context of HTEF in developing countries. Doing a comparative analysis, Figs. 1 and 4 show that higher levels of patented inventions are positively related to HTEF growth. Similarly, those countries with a lower number of patented inventions exhibit lower levels of HTEF growth. In real terms, Brazilian and Argentinian enterprises would benefit more from the higher patent activity than would Peruvian, Paraguayan, and Ecuadorian companies. The same holds for R&D workers. However, the influence of the presence of researchers in the nation on high-technology exporting firm growth is less (λ=0.588) compared to patents and R&D. Previous studies have found that yet a different measure of innovative activity, papers published in scientific journals, also is positively related to economic growth (Guerrero et al. 2015), firm performance (Kafouros et al. 2015), and commercial product development (Jong and Slavova 2014). In our research, publications in scientific journals, as was the case for patents and R&D, were found to have a positive relationship on HTEF growth. In particular, the mean number of scientific papers published annually 6728, per country is comparable to that found for developed countries, with the exception of Bolivia and Paraguay. However, while the measures of scientific activity are comparable between the developing countries of South American and the developed countries, high-tech LA-DC is not, raising the question as to why the impact of scientific contributions on HTEF growth is weaker in the Latin American context than in the developed countries? One explanation could be found in the different objectives and goals of universities between the Latin American countries and the developed nations. Another, as Czinkota and Pinkwart (2012) have concluded that knowledge generated at universities does not readily spillover for commercialization resulting in innovative activity in the private sector. They point out that managers and executives are rarely involved in the scientific activities of academia, such as reviewing papers for academic journals. Similarly, the same happens with the development of academic material (textbooks), where thought leaders in business and policy are virtually never involved or consulted for their views. This great divide between academia and the rest of society, and in particular business, might explain the low presence of LA-DC firms in foreign markets. In the region, just 25% of domestic enterprises export (average years 2008–2017), while the remainder is restricted to the domestic market.

5.2 Policy implications

The findings of this study have significant implications for practitioners. First, there is no doubt that the policy focus on fostering tertiary education has had a positive effect on HTEF growth. In the LA-DC countries analyzed, the rate of investment on TE is considered lower than in the more advanced economies. Therefore, we encourage LA-DC governments to incentivize the entrepreneurial sector by reducing taxes. In particular, policy needs to provide tax and other incentives to induce firms to invest in worker training. As Newman (2014) points out, we still have much work to do as not everyone has the same opportunities to obtain an education. There are many countries, especially in the rural zones of LA-DC, burden with high rates of illiteracy. The literature reviewed recommends that governments should subsidize those students with fewer resources (Lam and Liu 2011). In some Latin American countries, there are high rates of inequality—the levels of illiteracy in Bolivia, Ecuador, and Peru are 10%, 20%, and 30%, respectively (OECD 2017). This means that many students in those countries will never have the opportunity to obtain an advanced degree and, therefore, will not have access to the labor market. Consequently, domestic enterprises in those countries would be unable to find the necessary numbers of skilled workers they need to compete globally. Therefore, we would encourage governments to designate more investment in rural zones, given that, as we have shown here, tertiary education has a positive effect on HTEF growth.

Second, in the contemporary economic climate, and as a consequence of economic de-acceleration caused by the commodities, prices have been falling. Most Latin American countries (e.g., Brazil, Ecuador, and Chile) have reduced their budgets drastically for education and science. Therefore, if cutbacks remain, the domestic policies implemented over the years will not have an impact on the change of their productive model, focused on the development of high-tech entrepreneurial sectors. In this sense, as we argued, economies based on high-tech entrepreneurial sectors are less exposed to the fluctuation of commodities. A clear example of this are countries like Germany, UK, Japan, and so forth. However, we also should not forget that underlying the entrepreneurial sectors; there are enterprises which count on highly qualified personal, which is essential to compete overseas (Peña-Vinces et al. 2017). In fact, our research has shown the importance that well-trained human capital has for HTEF growth. Therefore, we encourage policymakers not to abandon their science policies to foster a reverse drain brain policy. Specifically, policies should focus on the repatriation of national researchers trained at the leading world-class universities. This would facilitate the future needs of highly skilled and high human capital labor by high-tech firms. Peña-Vinces et al. (2019) argue that science should not be considered as an expense but also as an investment. Investment in science, in the long run, accrues benefits for the country by enhancing its international competitiveness. At this time, a huge gap in human capital and R&D exists between the developing and developed nations. For example, the mean annual number of researchers working in R&D in Brazil between 2008 and 2017 was 732. By contrast, in Germany, it was over 4.000 researchers.

Third, in an era which is based on knowledge accumulation, a nation's economic prosperity depends on its ability to leverage its scientific infrastructure (Audretsch et al. 2011; Peña-Vinces et al. 2019). In this sense, academia and governments must work together to be capable of generating, attracting, and retaining prestigious researchers. However, Latin American science outputs are relatively low compared to those in the advanced economies. Nations might improve their scientific outputs by creating environments that allow the retention of the best talents in the region, as scientists can serve as bridges between universities and firms (Audretsch et al. 2011; Kafouros et al. 2015; Watkins et al. 2015).

Fourth, empirical evidence (Bodas Freitas et al. 2013; Yaşar and Paul 2011) shows that public incentives encouraging cooperation agreements between universities and industries helps the transformation of firms from traditional sectors (minerals and agriculture) to high-tech sectors. Thus, selling overseas (exporting) represents an opportunity not only for large MNEs but also for SMEs (Malca et al. 2019; Peña-Vinces and Urbano 2014). In this regard, we encourage Latin American governments to increase the volume of research activities through the provision of incentives to SMEs that invest in science.

Fifth, most of the Latin American public universities complain of a lack of funding from governments to develop science. However, as Whittemore (1998) suggests, universities must progressively become less dependent on undergraduate-teaching income. Rather, they must be able to obtain at least 50% of their income from other sources like research projects, spin-off companies, consultancy, and executive post-graduate (conferences, vacation courses, etc.).

Lastly, one of the main challenges decision-makers in less scientifically developed nations can leverage science in neighboring countries, which are more developed scientifically (Peña-Vinces et al. 2019). In the Latin American context, science outputs are concreted in three countries—Brazil, Argentina, and Chile. A regional office of science and public patents might be a solution or the creation of a cross-country fund for managing and the dissemination of science as was developed in the European Union.

5.3 Limitations and direction for future research

Most research has limitations, and our study is no exception. We highlight that scientific knowledge is cooperatively produced in most cases. Moreover, there is typically a collaboration among researchers from all around the world and not necessarily from a single country, which means that science does not only come from developing countries alone but also from cooperation with other researchers from other continents (e.g., Europe and Asia).

Our research proposes many questions that need to be answered by future research. One such interesting line of research could be to evaluate the effect that university education has on entrepreneurial productivity. Another significant line of research would be to analyze education from the dual perspectives of private and public education; in our study, these were treated as one. This could allow us to understand which (public or private) has a more significant impact on HTEF growth.

An issue not studied in our research was the effect that other, non-university types of academic institutions (training institutes/academies) might have on HEFT growth, given that other organizations co-exist in the region that also develop applied research and do not publish their findings in scientific journals. Indeed, in LA-DC institutes/academies of practical training account for around 50% of professional practice.

Because our study only examined HTEF growth, another possible important line of research could evaluate the effect of science and education on other entrepreneurial sectors such as services. The economic literature (Leten et al. 2014) has shown that science does not have the same impact in all sectors.

Because our research was focused on examining the impact of tertiary education on HTEF growth, we do not use all of the TE indicators that have been developed and applied in the extant literature. This study considered only those measures that might direct impact on entrepreneurial firms. However, there may be other measures that can be probed in future research, such as additional measures of education and human capital. Such future research might evaluate if education is linked to science or vice versa since there is no empirical evidence about how and why science and education might depend upon each other.

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Availability of data http://dx.doi.org/10.17632/rxb34r6gx7.1.

Appendix 1

See Table 4.

Table 4 Descriptive statistics before data' standardization

Variables (years 2008–2017)	Descriptive statistics				Test of normality	
	Min.	Max.	Mean	SD	Skewness	(SSE)
High-technology exporting firms growth	1.40	80.28	22.88	18.91	0.70	0.24
Researchers	50	1233	466	351	0.77	0.24
Articles published	32	53,667	6729	13,854	2.63	0.24
R&D	0.05%	1.34%	0.41%	0.33%	1.63	0.24
Patents	2	5480	756	1509	2.62	0.24
Expenditure on tertiary education	13.82%	43.51%	22.56%	6.3%	0.42	0.24
Workforce with advanced education	70.12%	89.79%	82.075%	3.86%	−1.10	0.24
Economic growth in dollars	1715	1,69,74,000	8771	4288	0.23	0.24
Fiscal pressure	49.87%	80.98%	66.25%	8.17%	−0.64	0.24
Services	38.64%	63.20%	52.00%	6%	−0.32	0.24

Notes (SSE) = Skewness standard error. A normal distribution is required in those studies with small samples ($N \leq 25$). Therefore, our Skewness values above 1.0 do not imply a violation of normality principals. SSE Values less than 1.00 point indicates a symmetrical distribution

Appendix 2

See Table 5.

Table 5 Correlations and test of collinearity

Correlations			Test of collinearity	
Variables	Partial (ZHighTECH)	Semi-partial (ZHighTECH)	Tolerance	VIF
Science	0.562	0.286	0.551	1.814
Tertiary Education	0.312	0.138	0.858	1.165
Economic growth	0.723	0.440	0.630	1.587
Fiscal pressure	−0.098	−0.041	0.674	1.483
Services	0.346	0.155	0.467	2.141

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