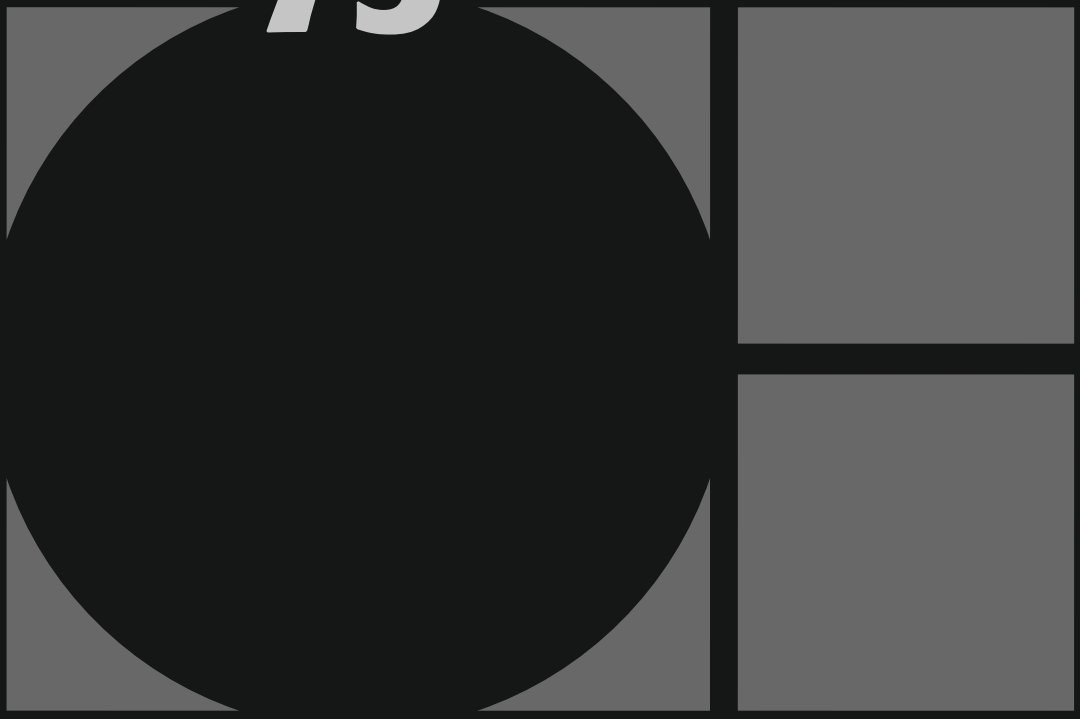
ESPECIAL
EDICIÓN

Alex Coad, Ross Brown
y Stefano Bianchini
(editores invitados)

CUADERNOS DE ECONOMÍA

ISSN 0121-4772

75



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UNIVERSIDAD
NACIONAL
DE COLOMBIA

CUADERNOS DE ECONOMÍA

VOLUMEN XXXVII
NÚMERO 75
NÚMERO ESPECIAL 2018
ISSN 0121-4772

Facultad de Ciencias Económicas
Escuela de Economía
Sede Bogotá

UNIVERSIDAD
NACIONAL
DE COLOMBIA

2018

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ARTÍCULO

HIGH-GROWTH FIRMS IN EUROPEAN COUNTRIES: THE ROLE OF INNOVATION

Agustí Segarra-Blasco
Mercedes Teruel
Elisenda Jové-Llopis

Segarra-Blasco, A., Teruel, M., & Jové-Llopis, E. (2018). High-growth firms in European countries: The role of innovation. ***Cuadernos de Economía*****, *37*(75), 637-670.**

This paper analyses the role that R&D and innovation has on the likelihood of a firm becoming a High-Growth Firm (HGF). The microdata is from the *Community Innovation* Survey provided by Eurostat, it covers the period 2008–2010, and we classify the EU countries into three clusters: Core countries, Mediterranean countries, and New EU Members. Our results show that there are large differences between each cluster. Technological innovations promote the likelihood of Core

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This paper is part of the research undertaken with the financial support of the Consolidated Research Group 2014-SGR-1395, Xarxa de Referència en Economia Aplicada (XREAP), the competitive project ECO2015-68061-R funded by the Ministry of Economics and Competitiveness (Spanish Government), and by European FEDER funds. We are grateful to Verònica Gombau and Anna Rovira for their research support. The authors would like to thank the two anonymous reviewers for useful suggestions and comments. The usual disclaimer applies.

Sugerencia de citación: Segarra-Blasco, A., Teruel, M., & Jové-Llopis, E. (2018). High-growth firms in European countries: The role of innovation. *Cuadernos de Economía, 37*(75), 637-670. doi: 10.15446/cuad.econ.v37n75.67721

Este artículo fue recibido el 13 de septiembre de 2017, ajustado el 21 de diciembre de 2017, y su publicación aprobada el 24 de enero de 2018.

countries becoming an HGF, non-technological innovations are a key determinant for Mediterranean countries, and in New EU members the drivers are more related to firm characteristics and international trade.

Keywords: High-growth firms, firm growth, innovation, European countries.
JEL: L11, L25, O30, O52.

Segarra-Blasco, A., Teruel, M., & Jové-Llopis, E. (2018). Empresas de alto crecimiento en países europeos: el rol de la innovación. *Cuadernos de Economía*, 37(75), 637-670.

Este artículo analiza el efecto de la I+D y la innovación sobre la probabilidad de que una empresa se convierta en una High-Growth Firm (HGF) para un conjunto de datos del *Community Innovation Survey* 2010. Agrupando distintos países de la Unión Europea en tres clústeres —*Core*, *Mediterranean*, y *New EU countries*— los resultados muestran claras diferencias. En los *core countries*, las innovaciones tecnológicas facilitan la probabilidad de convertirse en HGF, mientras que las no tecnológicas son determinantes clave en los *Mediterranean*. En los *new EU countries* los factores están más relacionados con características de la empresa y el comercio internacional.

Palabras clave: *High-growth firms*, crecimiento empresarial, innovación, países europeos.
JEL: L11, L25, O30, O52.

Segarra-Blasco, A., Teruel, M., & Jové-Llopis, E. (2018). Entreprises à forte croissance dans les pays européens : le rôle de l'innovation. *Cuadernos de Economía*, 37(75), 637-670.

Cet article analyse l'effet de l'innovation, de la recherche et du développement en termes de probabilité pour qu'une compagnie devienne une entreprise à forte croissance. Les microdonnées utilisées proviennent de l'enquête *Community Innovation* de Eurostat et couvrent la période 2008-2010. Nous classons les pays de l'Union européenne en trois groupes : pays principaux, pays méditerranéens et nouveaux membres. Nos résultats montrent qu'il existe de grandes différences entre chaque groupe. Les innovations technologiques augmentent la probabilité de ce que les compagnies des pays principaux se transforment en entreprises à forte croissance, les innovations non technologiques sont un élément déterminant pour les pays méditerranéens et, pour les nouveaux membres de l'UE, les facteurs de la croissance dépendent davantage des caractéristiques de chaque entreprise et du commerce international.

Mots-clés: entreprises à forte croissance, croissance de l'entreprise, innovation, pays européens.
JEL: L11, L25, O30, O52.

Segarra-Blasco, A., Teruel, M., & Jové-Llopis, E. (2018). Empresas de alto crescimento nos países europeus: o papel da inovação. *Cuadernos de Economía*, 37(75), 637-670.

Este artigo analisa o efeito da inovação, a pesquisa e o desenvolvimento em termos da probabilidade de uma empresa se tornar uma empresa de alto crescimento. Os microdados usados vêm da pesquisa *Community Innovation* de Eurostat e cobrem o período 2008-2010. Classificamos os países da União Europeia em três grupos: países centrais, países mediterrânicos e novos membros da UE. Nossos resultados mostram que existem grandes diferenças entre cada grupo. As inovações tecnológicas promovem a probabilidade de que as empresas dos países centrais se tornem empresas de alto crescimento, as inovações não tecnológicas são um fator determinante para os países do Mediterrâneo e, para os novos membros da UE, os promotores de crescimento estão mais relacionados com as características de cada empresa e com o comércio internacional.

Palavras-chave: empresas de alto crescimento, crescimento empresarial, inovação, países europeus.
JEL: L11, L25, O30, O52.

INTRODUCTION

The incorporation of new EU countries at the beginning of the 21st century has broken the equilibrium that existed between the Core and the Mediterranean economies. This process has created a new scenario in which transition economies have attracted an increasing amount of intra-European FDI flow, which facilitates firm entry. Based on this scenario, this paper analyses the drivers of innovation activities and the factors that promote the appearance of High-Growth Firms (henceforth HGFs) in thirteen EU members. We observe that the different business conditions in EU countries increases the heterogeneity on a country level. One of the main reasons for this is that factors which may act as an incentive for the emergence of HGFs in some developing countries may become a barrier in others.

R&D and innovation activity is one potentially positive factor that may boost a firm's growth. Direct and positive links between R&D, innovation, and productivity play a crucial role in developed countries (Mohnen, Mairesse, & Dagenais, 2006) while in developing countries the situation is more complex and heterogeneous. In the latter, firms find it difficult to build innovative networks in which information and knowledge help them to invest in R&D (Raffo, Lhuillery, & Miotti, 2008).[1]

The relative position of each country, institutional quality and the technological context affect the HGFs' growth capacity and their ability to invest in R&D activities (Hölzl, 2009). Recently, Daunfeldt, Elert and Johansson (2016), Krasniqi and Desai (2016) and Brown, Mawson and Mason (2017) have noted that these conditions are important for all countries, and they may cause non-homogenous impacts of R&D on firm growth.[2] This has been relevant since the promotion of R&D and innovation to foster HGFs and the development of a better manufacturing structure have become key issues in the current European objectives.

In this paper, we analyse the impact of innovation outputs on the likelihood of manufacturing firms becoming HGFs. We consider that the effect of innovation on firm growth differs between countries according to the macro conditions of each country and their distance with respect to the technological frontier.

To carry out our empirical analysis, we use a detailed dataset from the Community Innovation Survey (henceforth CIS), provided by Eurostat, covering the period 2008–2010 for thirteen European countries. Furthermore, we classify the EU countries into three clusters: Core countries, Mediterranean countries, and New EU countries. According to the characteristics of the data, we have applied

[1] Crespi and Zuniga (2012), using micro-data from innovation surveys across six Latin American countries (Argentina, Chile, Colombia, Costa Rica, Panama, and Uruguay), examine the determinants of technological innovation and the impact it has on productivity. They found that firm-level determinants of innovation are more heterogeneous than in developed countries.

[2] Similarly, Bravo-Biosca (2010, 2011) draws attention to entry and growth barriers and suggests structural reforms (product, labour, land, and financial barriers) to overcome differences between countries.

a biprobit model to calibrate the effects that technological (product and process innovations) and non-technological (organizational and marketing innovations) innovations have on the capacity of European firms to become HGFs. This allows us to control for unobserved characteristics that may potentially and simultaneously affect whether a firm becomes a manufacturing HGF, in addition to its capacity to innovate.

Our main results suggest that technological innovations increase the probability of becoming an HGF for a Core country while non-technological innovations are a key determinant for Mediterranean countries. Conversely, with respect to manufacturing firms in New EU Member countries, the more crucial variables are those closely related to firm characteristics and their internationalization. Hence, our paper sheds light on how the context where a firm operates may determine its capacity to grow and become an HGF. This approach is particularly of interest in the EU, where the incorporation of New EU members has considerably increased the heterogeneity among sectors and countries.

Our main contributions are the following: Firstly, we show evidence of the linkages between R&D and innovation and the probability of becoming an HGF for a group of New EU members. Secondly, our results shed light on how the higher intensity of manufacturing industries in New EU member countries has increased the presence of HGFs there. Finally, our results offer information on the key role that the transference of knowledge and innovation play so that manufacturing firms can become HGFs in those countries that have more robust Innovation Systems.

The paper is organized as follows: The second section, based on each country's characteristics, describes the literature on firm growth and the different role innovation plays. The third section presents the database and the main statistics. The fourth section explains the econometric methodology. Finally, the paper concludes with the main results and the resulting policy implications.

LITERATURE REVIEW

High-growth firms and innovation

Since Birch's (1979) seminal work, economists and policy-makers have paid considerable attention to HGFs.[3] Firms' innovative effort is key among the many factors analysed in the literature on firm growth (see Audretsch, Segarra-Blasco, & Teruel, 2014). According to the Schumpeterian theory of creative destruction, HGFs are created by entrepreneurs who can cope with market opportunities, develop their ideas, and transform them into innovations that will result in the rapid growth. Their capacity to generate new jobs and exploit their competitive advantages

[3] There is no commonly accepted definition for 'high-growth' firms (Parker, Storey, & van Witteloostuijn, 2010). The literature refers to fast-growth firms (Almus, 2002; Deutschmann, 1991; Storey, 1994), high-growth impact firms (Acs, Parsons, & Tracy, 2008), high-growth firms (Schreyer, 2000), "superstar" fast-growth firms (Coad & Rao, 2008), rapidly expanding firms (Schreyer, 2000), and gazelles (Birch, 1981).

represents a shake-out in the market distribution. Analysing the relationship between innovation and firm growth is of particular interest since HGFs that innovate face higher risks (Coad & Rao, 2010).

Firms' innovative performance promotes the development of their internal capabilities and this is a key factor in consolidating their market position. In a similar vein, Mason and Brown (2013) and Brown and Mawson (2016) highlight the importance of promoting "dynamic capabilities" rather than resource acquisition. Hence, it seems that innovative behaviour may be key to generating and fostering HGFs. Consequently, we might expect policy-makers to emphasize the generation of those "dynamic capabilities", which will lead firms to adapt and grow rapidly.[4]

It is unclear how, or even whether, firms' innovative capabilities directly impact their growth. This issue is even less clear when we observe HGFs. Early papers (Geroski & Machin, 1992; Storey, 1994) found a positive relationship between innovating firms and fast growth rates, but Smallbone, Leig, and North (1995) demonstrate that product management and market development are the factors that most consistently distinguish HGFs from other firms. More recently, Cucculelli and Ermini (2012) found product innovation had a positive impact on sales growth while Colombelli, Haned, and Le Bas (2013) show an unambiguous positive association between product, process, and organizational innovation and sales growth.[5] Hence, R&D and innovation performance are expected to have positive effects on a firm's growth; its innovation output, which reinforces its market position and; consequently, increasing its sales and expanding the labour force required for new production. Secondly, innovative performance potentially has no impact when new products or processes substitute the previous ones without having been changed.

Finally, new processes or non-technological innovations may have a negative impact on firm growth. For instance, innovations may entail adjustment costs or even reduce the number of workers (for example, the substitution of the labour force with machinery). However, even in this case, the long-term impact may be positive if there is an increase in productivity and a fall in price, which results in an increase in demand. These results are in line with the negative impact that innovation activity has on the lower quantiles growth distribution (Coad & Rao, 2008; Coad, Segarra, & Teruel, 2016; Segarra-Blasco & Teruel, 2014).

Heterogeneity at country level

In general, previous analyses of the determinants of a firm's HGF propensity have focused on individual countries. However, countries differ in terms of their market structure and institutional framework; consequently, innovation may play different

[4] Previous empirical evidence confirms that HGFs are more R&D intensive (Coad et al., 2016; Segarra-Blasco & Teruel, 2014). According to Mazzucato and Parris (2015, pp. 15), "HGFs have the most to gain from increasing their R&D intensity. However, the benefits of investing in R&D are conditional on the competitive environment, even for firms in the top growth quantiles".

[5] For R&D or patents, there is broader evidence from authors such as Bottazzi, Dosi, Lippi, Pammolli, and Riccaboni (2001), Coad et al., (2016), Segarra-Blasco and Teruel (2014) and Stam and Wennberg (2009).

roles in the generation of HGFs. However, there has not been much work undertaken that analyses cross-country behaviour (Brown et al., 2017); the most outstanding exceptions come from Bravo-Biosca (2010, 2011), Bravo-Biosca, Criscuolo and Menon (2016), Hölzl (2009), Krasniqi and Desai (2016), Navaretti, Castellani and Pieri (2014), Schreyer (2000), Segarra-Blasco, Teruel-Carrizosa, and Jové-Llopis, (2016), and Teruel and de Wit (2017).

Schreyer (2000) analysed the behaviour of HGFs for OECD countries at industry level in the 1980s and 1990s. His results show that HGFs are more R&D intensive. Bravo-Biosca (2010, 2011) analysed the industrial behaviour of twelve OECD countries between 2002 and 2005. His focus is on the relationship between total factor productivity (TFP) growth and the growth distribution. He finds that countries with a larger share of firms that remain static show lower productivity growth.

Meanwhile, Teruel and de Wit (2017) explore data from seventeen OECD countries between 1999 and 2005. These authors focus on the incidence of macroeconomic determinants from three driving forces behind high growth: entrepreneurship, institutional settings, and opportunities for growth. Hölzl (2009) explores data from sixteen countries during the period 1998–2000. He finds that HGFs exhibit a greater R&D intensity than non-HGFs in countries closer to the technological frontier. Similarly, Segarra-Blasco et al., (2016) analyse the effect innovation has on the capacity to become an HGF using CIS microdata covering the 2006-2008 period for fifteen European countries that was provided by Eurostat. They examine HGFs in countries that invest heavily in R&D in comparison with those with a lower level and found that drivers to innovate and become an HGF differ across EU member countries. In leader countries, HGFs are related to R&D and innovation, whereas in laggard countries HGFs depend on firms' characteristics and market dynamics.

Similarly, for a sample of French, Italian, and Spanish manufacturing firms with more than ten employees in the period from 2001 to 2008, Navaretti et al., (2014) found that in HGFs the number of employees in R&D activities and graduates is positively correlated with firm growth in upper quantiles. Hence, their evidence supports the thesis that HGFs will be positively affected by their innovation capabilities. More in line with our analysis, but using macroeconomic data for 26 transitional countries between 1998 and 2009, Krasniqi and Desai (2016) highlight the influence that formal and informal institutions have on the share of HGFs. Their results also highlight the importance of the velocity of transition and the influence of these institutional factors.

From a complementary perspective, Bravo-Biosca et al., (2016) examine the impact of employment protection legislation and financial institutions on firm growth dynamics using a recently-developed database that captures the full distribution of firm growth rates across several countries (the United States, Canada, and eight European countries: Austria, Denmark, Finland, Italy, the Netherlands, Norway, Spain and the United Kingdom). Their empirical analysis shows that both employment protection legislation and financial institutions have a heterogeneous

impact across the distribution of firm growth, and therefore, have an impact on the speed of the resource reallocation process. Finally, from a set of African countries, Goedhuys and Sleuwaegen (2010) analyse the growth performance of a large set of entrepreneurial firms and the determinants of HGFs in eleven Sub-Saharan African countries with a sample of firm-level data collected by the World Bank Investment Climate Survey. They found that public intervention should aim to raise capabilities through an improved educational system that upgrades the skills of both the entrepreneurs and the labour force.

Although the relationship between innovation and HGFs has been examined for countries that have been integrated into the EU for some time, this evidence does not exist for new members. Following the classification adopted by Hölzl (2009), we have distributed the thirteen European countries included in our dataset into three groups that present different levels of technological development: Core countries, Mediterranean countries, and New EU countries.[6]

Recent empirical studies have found that the institutional and technological contexts in which European firms operate affect not only HGFs' growth capacity but also their capacity to invest in R&D activities. Hölzl's (2009) findings support the importance of a country's technological development so that R&D has an incidence on HGFs. His results point out that, in technologically developed countries, HGFs are more R&D intensive that non-HGFs. Firm's incentives to invest in R&D and the innovation outcomes vary widely among countries. In developing countries, firms have fewer incentives to invest in R&D since the risk is higher and the returns appear only after long periods. In these countries, innovative firms invest less in R&D and are more prone to invest in technological development. They also acquire machinery and imitate rather than innovate. More frequently, firms in less developed countries introduce more incremental innovations and register fewer patents. On the macroeconomic level, Krasniqi and Desai (2016) found evidence of the positive influence innovation has on the existence of HGFs in various countries.

The incorporation of New EU members

Over the last two decades, the Eastern European emerging and transition economies have experienced an important structural change. However, the starting point of the Eastern economies is diverse. Before the transition period, the Czech Republic was already R&D oriented, Hungary and Poland had a high share of R&D, and Hungary was technologically open (Radosevic & Auriol, 1999).

The transition process from the post-socialist period to EU institutional rules has been complex and difficult, especially on the institutional level. One key institution

[6] Verspagen (2010) found important differences in terms of innovation and growth dynamics between European regions and proposed four geographical groups: Southern Europe, Eastern Europe, and two groups in Western and Northern Europe. This proposal is closely aligned with the European countries grouping that this work used.

to foster innovation capabilities and the capacity to grow is the Innovation System. Individual companies, domestic businesses, and sectoral determinants primarily drive the Innovation Systems of these New EU countries. As Radosevic (1999) remarks, the innovation patterns at firm and sector level are diverse. Additionally, the links between firms' innovation patterns and Innovation Systems are weak and differ between sectors and countries. Hence, the transition that these New EU countries have experienced is a discontinuous process which may affect the capacity of their economies, in terms of innovation, to catch up with the developed economies.

Foreign direct investment (FDI) is a potential booster of the Innovation System in new countries. For a panel of sixteen Eastern European transition countries, Krammer (2009) found that the globalization and the integration of the EU highly facilitate the development of innovations through FDI inflows and trade. In this sense, the slow removal of trade barriers, reduction of bureaucracy, and advances in governance decreased transaction costs, which facilitated the inflow of FDI.

These countries need to develop the broad range of institutions and policies that are necessary to create conditions for favourable economic growth to catch up with more developed economies (Globerman & Shapiro, 2002). In this sense, inadequate bureaucracy is a deterrent to foreign investors as increased transaction costs adversely affect the profitability of investment projects. Bevan and Estrin (2004), using panel data on bilateral flows of FDI between 1994 and 2000, observe that the most important influences on the FDI flows from EU countries to New EU members are unit labour costs, market size, and proximity; the host country risk is a not significant determinant.

In general, Eastern European countries that have a large market, good infrastructure, transparent institutions, and an educated labour force are more likely to receive more FDI from traditional EU countries in the tradable sectors (Globerman & Shapiro, 2002; Kinoshita, 2011).

According to Bevan and Estrin (2004), countries that have successfully implemented transition policies have been promised a relatively speedy EU membership, which further accelerates FDI and, in turn, generates more growth and development. In contrast, countries that were less successful in implementing transition policies attracted fewer FDI inflows from EU members. Despite the growth of FDI inflows to the New EU members, the empirical evidence shows that, during in the 1990s, there was a clear negative impact on the amounts of FDI inflows received by traditional European countries (Brenton, Di Mauro, & Lücke, 1999).

Furthermore, the incorporation of New EU members has led to the relocation of parts of their production chain from the Mediterranean countries to new European countries. This relocation has produced negative effects on production and employment growth in Mediterranean countries, especially for the services sector and in their most traditional industries. The impact has not been positive for employment in technologically intensive manufacturing industries and business services (Savona & Schiattarella, 2004). In fact, this relocation process has caused,

according to Pianta, Lucchese and Nascia (2016), Mediterranean countries to have very few leading firms in global markets. They have also experienced a continuing loss of ownership of major firms to foreign investors.

Table 1 shows data on how New EU members have had a greater capacity to transform their manufacturing activities and to preserve higher levels of industrialization than other EU countries. In the EU, the share of manufacturing value added has decreased nearly five points in the Core countries, the Mediterranean countries, and the New EU members. The cluster of New EU members has had to go through a major adjustment process but, nonetheless, the share of the manufacturing activities is still larger than in the other countries.

Since the 1980s the importance of the manufacturing industry has considerably declined. The impact of the current recession has exacerbated this situation. Within this context, the EU's goal to increase manufacturing shares to 20% of GDP by 2020 should be a main objective in terms of European countries' industrial policy. However, according to the dynamics registered over recent years, this objective often appears to be unattainable.

Table 1 presents the development of high technology exports. The data is explicit. While in the Core countries, the importance of technology-intensive exports remains stable, for the New Members, high-tech exports have increased to a level of ten per cent of total exports, and for the Mediterranean countries, these exports remain at a moderate percentage that barely exceeds five percent. This evidence highlights those asymmetries that have occurred since the recession in the European Union.

The slowdown experienced by European manufacturing industries has not similarly affected all countries in the European Union. Furthermore, these differences have increased in European economies with the incorporation of the emerging and transition economies in Central and Eastern Europe into the European Union. During this process of an increasing openness towards Eastern European countries, the traditional equilibria among the economies that form the Core and the Mediterranean countries has shifted considerably.

This trend poses a challenge for the EU. Therefore, analysing the occurrence of HGFs in the manufacturing sector may be interesting, especially when we undertake a comparison between the Core, the Mediterranean countries, and the new EU members. We assume that firms in more advanced countries are more closely related with R&D investment and the innovative activity of the firm while firm specific characteristics and institutional framework will be key for the appearance of HGFs in New European countries. The Mediterranean countries are suffering from the constraints of the current crisis and their lack of innovative capabilities.

Table 1.
Manufacturing Share and High-Tech Exports in European Countries. 1995-2015.

Manufacturing share (% of total GDP)									
Cluster countries	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
European Union (28)	16.52	16.07	14.73	15.41	15.74	15.47	15.48	15.60	15.92
Core countries	15.66	15.28	14.05	14.85	15.19	15.00	15.04	15.07	14.89
Mediterranean countries	15.97	15.43	13.80	14.22	14.36	14.10	14.23	14.44	14.77
New EU Members	20.24	19.63	18.76	19.22	19.82	19.72	19.46	20.46	20.73
Exports of high technology products (% of total exports)									
European Union (28)	16.10	15.40	17.10	16.10	15.40	15.70	15.30	15.70	17.00
Core countries	16.57	16.39	19.16	17.01	15.51	16.50	15.40	15.49	16.26
Mediterranean countries	5.35	5.35	5.20	4.73	4.60	4.48	4.50	4.80	5.18
New EU members	7.10	7.86	8.62	9.13	8.99	8.70	9.72	9.32	10.60

Note: Core countries include Belgium, Denmark, Germany, France, Luxembourg, the Netherlands and the UK; Mediterranean countries include Greece, Italy, Portugal and Spain; and New EU countries include Bulgaria, the Czech Republic, Estonia, Croatia, Cyprus, Latvia, Lithuania, Poland, Romania, Slovenia and Slovakia.
Source: Eurostat.

THE DATABASE AND SOME DESCRIPTIVE STATISTICS

Database

Following the guidelines set out in the *Oslo Manual* developed by the OECD -Eurostat (2005), several countries have designed a common questionnaire, the CIS, for firms' innovation activities. CIS surveys are carried out every two years by EU member states as well as several other non-EU countries (e.g. Norway, Iceland). Hence, the CIS facilitates access to a range of information related to how European firms innovate. Since the data are only available for a limited set of EU members' states, scholars must focus their work on a restricted sample of countries. Although the database provided by Eurostat presents some limitations (such as the lack of representativeness at country level, among countries close to the technological frontier, and the high presence of dichotomous variables), the final source allows a series of relevant conclusions to be reached.

Our database is limited to CIS 2010, which covers the period 2008–2010. This paper analyses the determinants of HGFs using an extensive sample of firms belonging to thirteen countries classified into three clusters according their gap

with the European technological frontier: Core country (Germany), Mediterranean countries (Portugal and Spain), and New EU members (Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Romania, Slovenia and Slovakia).

The main advantages of the CIS are: i) it contains detailed information on the innovation behaviour at firm level in much greater detail than in other datasets; ii) CIS data are internationally comparable based on a common survey questionnaire and methodology. However, there are also some drawbacks. First, CIS is a cross-sectional dataset. Second, CIS data has little financial information, which is a crucial variable for firm growth. Finally, and most importantly, the country coverage varies substantially depending on the indicators considered. This limits our capacity to incorporate variables that are available for some countries but not for others.

Finally, our database was subject to a filtering process. First, we selected firms from the manufacturing sectors (Divisions 10-33 NACE classification). To control for outliers, we restricted observations to those firms with a growth or decline of sales and employees under 250% per year. Although the filtering process reduced the initial database from 97,496 to 40,822 firms, the sampling improved the data consistency.

Descriptive statistics

The definition of HGFs follows the criteria adopted by the OECD and Eurostat in the Manual on Business Demography Statistics (Eurostat-OECD, 2007, pp. 61) which defines HGFs as: "All enterprises with average annualized growth in employees (turnover) greater than 20% a year, over a 3-year period, and with 10 employees at the beginning of the observation period". The CIS data do not include the number of employees (only a variable recoded between three size classes: firms with 10–49, 50–249, and 250 or more employees); it also does not contain information about turnover. Given the restrictions of our database, we identify HGFs as firms with a turnover growth equal to or greater than 20% between 2008 and 2010. We deflated this variable using an industrial price index.

Our final data contains 40,822 firms, of which 3,377 (8.27%) were HGFs (Table 2). The percentage of HGFs in the Core countries is 5.73%, in the Mediterranean countries is 5.24%, while, in the New EU countries is equal to 10.81%. The difference in the percentage of HGFs in the Core and Mediterranean countries versus the New EU countries may be explained in part by the fact that New EU countries are benefitting from still being in a process of economic convergence and having weaker market structures.

Table 2.
CIS Samples by Countries

Countries	Number of firms	Number of firms (%)	HGFs (%)	Sales growth 08-10 (%)
Core country				
Germany	2,809	6.88	5.73	1.42
Mediterranean countries				
Portugal	3,226	7.90	7.19	-0.57
Spain	13,140	32.19	4.76	-9.17
New EU members				
Bulgaria	7,468	18.29	13.83	-0.53
Croatia	1,038	2.54	6.45	-10.07
Cyprus	298	0.73	12.75	5.44
Czech Republic	3,115	7.63	6.90	-4.71
Estonia	719	1.76	7.93	-5.74
Hungary	2,544	6.23	7.67	-5.11
Lithuania	723	1.77	13.55	-0.62
Romania	4,123	10.10	11.76	-11.11
Slovakia	708	1.73	13.28	4.56
Slovenia	911	2.23	8.34	-0.16
TOTAL	40,822	100.00	8.27	-5.47

Source: Authors' own calculations based on CIS2010, Eurostat.

Table 3 shows the main features that distinguish HGFs between the three country clusters that are considered in this study:

a) Eastern countries' moderate propensity to invest in R&D or cooperate in R&D projects with other partners reflect the weakness of their Innovation Systems at the regional and country level to facilitate innovation activities in their local firms.

b) Firms in Core and Mediterranean countries introduce more innovations, both technological and non-technological, than New EU members. Furthermore, countries that have been integrated into the EU project for many years receive more public funds that New EU members.

Table 3.
Descriptive Statistics by Country Groups (mean values)

	Whole sample	**Core**	**Mediterranean**	**New EU members**
HGF	0.0818	0.0573	0.0524	0.1089
Innovative	0.5180	0.8276	0.6139	0.4053
Innovation input				
intRD	0.2433	0.5774	0.3064	0.1523
extRD	0.1263	0.3075	0.1538	0.0819
Cooperation	0.1477	0.3104	0.1583	0.1186
Cooperation partners				
Internal	0.0521	0.0961	0.0487	0.0490
Market	0.1196	0.2168	0.1226	0.1048
Institutional	0.0836	0.2107	0.0981	0.0567
Innovation output				
TechInnov	0.4174	0.7130	0.5303	0.2937
Non-TechInnov	0.3564	0.5592	0.3987	0.2980
Individual characteristics				
Size				
Size <50	0.5811	0.3819	0.6473	0.5568
Size 50-249	0.3170	0.3221	0.2883	0.3381
Size >249	0.1017	0.2958	0.0642	0.1049
Group	0.2560	0.4179	0.2622	0.2303
Public funds				
Regional	0.0540	0.1206	0.1060	0.0060
National	0.0914	0.1723	0.1233	0.0573
EU	0.0388	0.0744	0.0241	0.0450
Export	0.5994	0.6361	0.6325	0.5697
Aggregate determinants				
Sectoral value added	-0.0750	0.0205	-0.1405	-0.0379
MES	23.4487	61.9115	16.7945	23.4885
Sectoral productivity	5.3519	6.2408	5.9616	4.7755
Observations	40,822	2,809	16,366	21,647

Source: Authors' own calculations based on CIS2010, Eurostat.

Table 4 presents statistics for HGFs and Non-HGFs in the three groups of countries. The table´s main characteristics are the following:

a) The proportion of those HFGs that state they are engaged in R&D activities is greater in the Core and Mediterranean countries than in New EU member countries. HGFs in countries close to the technological frontier that are involved in R&D also undertake more intensive cooperation agreements than HGFs in countries that have recently been integrated into the EU.

b) In contrast, HGFs in New EU Member countries are less innovative as they have a lower percentage of R&D effort and technological and non-technological innovation in comparison with Core and Mediterranean countries.

c) In general, the HGFs in Core and Mediterranean countries are more innovative, more active in investing in R&D, cooperate more in R&D projects with other firms or institutional partners, and are more likely to receive regional and national public funds.

d) However, in New EU Member countries, Non-HGFs are slightly more innovative than HGFs. They are more likely to invest larger amounts in R&D (internal and external) and cooperate more in R&D projects with other partners. Moreover, Non-HGFs in New EU countries export less than HGFs.

In short, the values reflected in the three clusters of countries, together with the substantial significance of the t-test, suggest that the profiles of HGFs and non-HGFs from countries that have been EU members for longer periods of time differ slightly from those in New Member countries.

ECONOMETRIC MODEL

We apply a bivariate probit as the econometric methodology to analyse the effect that innovation activity has on the probability of becoming an HGF. Since our database is cross-sectional, our estimations will not be able to capture the impact that innovation has on the probability of being an HGF. Hence, we consider a simultaneous model in which the innovation inputs, innovation outputs and the capacity of the firm to become an HGF are interrelated.

Our model follows the CDM approach (Crepon, Duguet, & Mairesse, 1998) where the firm makes an effort to innovate, which has an impact on innovation output and, thus, there is an impact on firm performance. Hence, our model is composed of two equations:

$$Innov_{it} = X'_{it}\beta_{11} + \gamma_{11} intRD_{i,t} + \gamma_{12} extRD_{i,t} + Z'_{i,t}\beta_{12} + \varepsilon_{1i,t} \quad (1)$$

$$HGF_{it} = X'_{it}\beta_{21} + \gamma_{21} Innov_{i,t} + \varepsilon_{2i,t} \quad (2)$$

Table 4.
Descriptive Statistics of HFGs and Non-HGFs by Country Groups (mean values)

	Whole sample		**Core**			**Mediterranean**			**New EU members**		
	HGFs	**Non-HGFs**	**HGFs**	**Non-HGFs**	**Mean difference**	**HGFs**	**Non-HGFs**	**Mean difference**	**HGFs**	**Non-HGFs**	**Mean difference**
Innovative	0.4726	0.5221	0.8757	0.8247	-0.051	0.6701	0.6108	-0.059***	0.3731	0.4092	0.036***
Innovation input											
intRD	0.2090	0.2464	0.6956	0.570	-0.125**	0.3659	0.3031	-0.062***	0.1187	0.1564	0.037***
extRD	0.1166	0.1271	0.3664	0.3040	-0.624	0.1934	0.1516	-0.041***	0.0716	0.0832	0.011
Cooperation	0.1445	0.1480	0.4534	0.3017	-0.151***	0.1969	0.1562	-0.040***	0.1043	0.1203	0.016
Cooperation partners											
Internal	0.0488	0.0524	0.0993	0.0959	-0.003	0.0594	0.0481	-0.011	0.0415	0.0499	0.008
Market	0.1169	0.1199	0.3478	0.2088	-0.138***	0.1526	0.1209	-0.031**	0.0882	0.1069	0.018**
Institutional	0.0758	0.0843	0.3478	0.2024	-0.145***	0.1200	0.0969	-0.023	0.0411	0.0580	0.016***
Innovation output											
TechInnov	0.3713	0.4215	0.8074	0.7073	-0.100**	0.5804	0.5275	-0.052**	0.2654	0.3002	0.031***
Non-TechInnov	0.3485	0.3571	0.6397	0.5543	-0.085	0.4825	0.3941	-0.088***	0.2798	0.5571	0.020
Individual characteristics											
Size											
Size <50	0.5873	0.5805	0.5155	0.3738	-0.141***	0.6771	0.6457	-0.031	0.5547	0.5571	0.002
Size 50-249	0.3118	0.3175	0.2981	0.3236	0.250	0.2668	0.2895	0.022	0.3290	0.3392	0.010
Size >249	0.1042	0.1015	0.1863	0.3024	0.116**	0.0559	0.0647	0.008	0.1162	0.1035	-0.012
Group	0.2641	0.2553	0.1099	0.4184	0.008	0.2983	0.6457	-0.038	0.2417	0.2289	-0.012

(*Continued*)

Table 4.
Descriptive Statistics of HFGs and Non-HGFs by Country Groups (mean values) (*continuation*)

	Whole sample		Core			Mediterranean			New EU members		
	HGFs	**Non-HGFs**	**HGFs**	**Non-HGFs**	**Mean difference**	**HGFs**	**Non-HGFs**	**Mean difference**	**HGFs**	**Non-HGFs**	**Mean difference**
Public funds											
Regional	0.0461	0.0547	0.2484	0.1129	-0.135***	0.1165	0.1054	-0.011	0.0067	0.0059	-0.001
National	0.0826	0.0922	0.3291	0.1627	-0.166***	0.1561	0.1215	-0.034**	0.0390	0.0589	0.019***
EU	0.0438	0.0383	0.1055	0.0725	-0.033	0.0396	0.0233	-0.016**	0.0411	0.0457	0.004
Export	0.5904	0.6002	0.6894	0.6329	-0.056	0.6095	0.6338	0.024	0.5767	0.5688	-0.007
Aggregate determinants											
Sectoral value added	-0.0521	-0.0771	0.0448	0.0190	0.033	-0.1122	-0.1418	-0.024***	-0.0349	-0.0383	-0.003
MES	27.3069	23.1007	70.8243	61.3696	-9.454	15.0380	16.7205	-1.411**	27.6740	22.9768	-4.697***
Sectoral productivity	5.1030	5.3743	6.1891	6.2439	0.054	0.6816	5.9626	0.018	4.7229	4.7819	0.058**
Observations	3,377	37,445	161	2,648		858	15,508		2,358	19,289	

Note: comparison of the two samples (HGFs versus Non-HGFs) using the statistical t-test. ** and *** indicates levels of significance to 5 and 1%.
Source: Authors' own calculations based on CIS 2010, Eurostat.

and where

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \end{pmatrix} \sim N\left\{ \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \right\}$$

Equation (1) estimates the probability that a firm innovates.[7] *Innov* is a dummy variable equal to 1 if the firm reports having introduced new or significantly improved technological or non-technological innovations between 2008 and 2010. As explanatory variables specific to this equation, we include the innovation inputs such as the internal R&D (*intRD*) and external R&D activity (*extRD*) and a set of explanatory variables (*Z*). These belong to the different types of cooperation partners such as whether the firm cooperates with other firms within the enterprise group (*Internal*), suppliers, clients, competitors or private R&D institutions (*Market*) or universities, public research organizations, or technology centres (*Institutional*).

Equation (2) calculates the probability of being an HGF. *HGF* is a dummy variable equal to 1 if the firm is an HGF as measured in terms of sales. In this second equation, we have distinguished between our main explanatory variable between technological (*TechInnov*) and non-technological innovations (*Non-TechInnov*) during the 2008–2010 period.

Both equations control for common explanatory variables (*X*). First, we introduce firm characteristics such as firm size (dummies that identify firms between 50 and 249 employees and those with 250 or more employees), if the firm belongs to a group, if the firm exports or cooperates, and if it has received public funds (at regional, national, or EU level). Finally, we include macroeconomic variables such as sectoral valued added, sectoral minimum efficient scale, sector productivity, country dummies and sectoral dummies.

We assume that ε_i are independently and identically normally distributed residuals. The parameter ρ identifies the correlation between the disturbances and accounts for omitted or unobservable factors that simultaneously affect the decision to innovate and the likelihood of becoming an HGF.[8]

Our results show that the coefficient ρ is significantly different to 0 when we simultaneously estimate all the countries. However, when we break this down using our three categories of country, the parameter is not significant. We present the joint results, but our results remain similar when we estimate the univariate probit models.

The bivariate probit regression model has several advantages. First, it allows the propensity to innovate and the capacity to become an HGF to be estimated together. Second, it allows unobserved common determinants to be controlled. The probability of innovating and the probability of becoming an HGF must be estimated

[7] See the definitions of variables in Table A.1 and Table A.2 for the correlation matrix.

[8] If ρ is equal to 0, the probability of becoming an HGF will not be correlated with the error term in Equation (1) and the probability of innovating will not be affected by the error term in Equation (2). Whereas, if ρ is different from 0, a joint estimation is required to obtain consistent estimates.

simultaneously since there may be unobserved characteristics that explain the a firm's capacity to innovate and their capacity to become an HGF (see for instance Coad et al., (2016); Segarra-Blasco and Teruel (2014). Also, Decker, Haltiwanger, Jarmin and Miranda, (2016) recently pointed out the relationship between the presence of Young Innovative Companies (YICs) and HGFs.

Furthermore, the uncertainty associated with the innovation output also depends on unobservable firm-specific risk factors, which may affect the capacity of a firm to introduce its goods into the market and, consequently, this may affect its capacity to become an HGF.

RESULTS

Table 5 reports the results of the average marginal effects from the innovative activity determinants and being an HGF (in terms of sales). We report the marginal effects for the whole database and for the three groups of countries considered in this study (Core, Mediterranean and New EU members).

The following observations are the main results for the determinants that affect the probability of being an innovative firm: In terms of the impact the R&D investment has on the probability of innovating, the estimation across all country clusters shows a positive and highly significant relationship between investments in internal and external R&D as well as the probability of introducing both technological and non-technological innovations.

The role assigned to the characteristics of firms is in line with previous results. First, medium and larger firms show a larger propensity to innovate than small firms. Second, firms belonging to a group are more likely to innovate, especially in Mediterranean and New member countries. This may be because firms belonging to a group have greater support in carrying out innovative activities. Third, firms that cooperate and export show a greater correlation with being an innovative firm. Institutional cooperation seems to be more important for Core country firms whereas Mediterranean firms rely more on market cooperation such as competitors, suppliers, or clients. In contrast, cooperation with other firms that belong to the group and with competitors, suppliers, or clients positively affects New EU member countries' ability to innovate.

In terms of access to public funds, we observe that this variable has a positive correlation with the likelihood of being an innovative firm (both technological and non-technological) in all countries. The availability of regional public funds seems to be influential for Core firms while both regional and national public funds are important for Mediterranean countries. Furthermore, in addition to regional and national public funds, EU subsidies show a greater correlation with the probability of being an innovative firm in the New EU member group.

Table 5.
Average Marginal Effects of Bivariate Probit of the Probability of Innovating and the Probability of Becoming an HGF

	Whole sample	**Core country**	**Mediterranean countries**	**New EU members Countries**
Probability of becoming an HGF				
Innovation output				
TechInnov	-0.0003	0.0335*	0.0080	-0.0077
	(0.004)	(0.014)	(0.005)	(0.007)
Non-TechInnov	0.0126**	0.0112	0.0160***	0.0070
	(0.004)	(0.010)	(0.004)	(0.007)
Individual characteristics				
Size				
Size:50-249	-0.0125***	-0.0385**	-0.0140**	-0.0069
	(0.003)	(0.012)	(0.004)	(0.005)
Size>249	-0.0204***	-0.0681***	-0.0282***	0.0025
	(0.004)	(0.013)	(0.006)	(0.008)
Group	0.0151***	0.0183	0.0152***	0.0209***
	(0.003)	(0.010)	(0.005)	(0.005)
Cooperation	0.0004	0.0016	0.0039	-0.0015
	(0.004)	(0.011)	(0.005)	(0.009)
Public funds				
Regional	0.0175**	0.0300*	0.0017	0.0466
	(0.006)	(0.012)	(0.006)	(0.002)
National	0.0002	0.0274*	0.0057	-0.0285*
	(0.005)	(0.012)	(0.005)	(0.011)
Europe	0.0043	-0.0124	0.0136	0.0083
	(0.007)	(0.016)	(0.0101)	(0.011)
Exports	0.0001	-0.0153	-0.0130**	0.0193***
	(0.03)	(0.010)	(0.004)	(0.005)
Mediterranean countries	0.0020			
	(0.007)			
New EU members	0.0290***			
	(0.008)			

(*Continued*)

Table 5.
Average Marginal Effects of Bivariate Probit of the Probability of Innovating and the Probability of Becoming an HGF (*continuation*)

	Whole sample	**Core country**	**Mediterranean countries**	**New EU members Countries**
Probability of becoming an HGF				
Aggregate determinants				
Sectoral Value added	0.0082	-1.9933	0.0228	-0.0059
	(0.005)	(2.230)	(0.051)	(0.008)
MES	0.0003***	0.0008	-0.0001	0.0003*
	(0.001)	(0.001)	(0.001)	(0.001)
Sectoral Productivity	-0.0273***	-0.0649	0.0108	-0.0251***
	(0.002)	(0.048)	(0.018)	(0.005)
Probability of innovating				
Innovation input				
IntRD	0.3613***	0.2024***	0.3275***	0.4326***
	(0.013)	(0.016)	(0.008)	(0.012)
ExtRD	0.1381***	0.0444*	0.1050***	0.2399***
	(0.013)	(0.024)	(0.016)	(0.028)
Individual characteristics				
Size				
Size:50-249	0.0525***	0.004	0.0587***	0.0609***
	(0.004)	(0.016)	(0.008)	(0.006)
Size>249	0.1195***	0.0965***	0.1090***	0.1182***
	(0.009)	(0.018)	(0.019)	(0.012)
Group	0.0418***	0.0185	0.0449***	0.0511***
	(0.005)	(0.016)	(0.009)	(0.007)
Cooperation partners				
Internal	0.0942**	-0.0261	0.0481	0.1156*
	(0.030)	(0.045)	(0.045)	(0.048)
Market	0.3129***	0.0476	0.2358***	0.3961***
	(0.016)	(0.030)	(0.023)	(0.0252)
Institutional	-0.0519*	0.0554	0.0082	-0.1316**
	(0.020)	(0.030)	(0.026)	(0.043)

(*Continued*)

Table 5.
Average Marginal Effects of Bivariate Probit of the Probability of Innovating and the Probability of Becoming an HGF (*continuation*)

	Whole sample	**Core country**	**Mediterranean countries**	**New EU members Countries**
Probability of innovating				
Public funds				
Regional	0.1570***	0.0957*	0.1841***	0.4753***
	(0.019)	(0.039)	(0.019)	(0.112)
National	0.1095***	0.0280	0.0737***	0.1907***
	(0.015)	(0.031)	(0.018)	(0.031)
Europe	0.1847***	0.0012	0.0567	0.2101***
	(0.022)	(0.050)	(0.042)	(0.027)
Exports	0.091***	0.0331*	0.1205***	0.0782***
	(0.004)	(0.013)	(0.006)	(0.006)
Mediterranean countries	-0.1244***			
	(0.0121)			
New EU members	-0.2420***			
	(0.013)			
Aggregate determinants				
Sectoral value added	0.0158*	-7.7933**	0.1645	0.0254*
	(0.008)	(2.819)	(0.102)	(0.010)
MES	-0.0006***	0.0019*	-0.0056**	-0.0001
	(0.001)	(0.001)	(0.002)	(0.002)
Sectoral productivity	-0.0101*	-0.1565**	-0.0174	-0.0127
	(0.004)	(0.059)	(0.040)	(0.007)
Rho (ρ)	-0.0431*	-0.1601	-0.0407	-0.0358
	(0.020)	(0.106)	(0.038)	(0.027)
Wald test of χ^2	6321.69	6258.81	2622.63	2520.42
	0.000	0.000	0.000	0.000
Observations	40,822	2,809	16,366	21,647

HGF high-growth firms
Core country: Germany; Mediterranean countries: Portugal and Spain; New EU members' countries: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Romania, Slovenia, and Slovakia.

Estimations control for country and sector dummies. *; **; *** indicate levels of significance equal to 10.5 and 1 %. Robust standard errors in parentheses.
Source: Author's own calculations based on CIS2010, Eurostat.

Concerning the aggregate variables, we observe that the sectoral value added shows a significant positive impact on New EU members' probability of innovating while the relationship is significant and negative for the Core country. The different impact shows that the firms that have a larger probability of innovating in the New EU countries are in sectors with larger added value growth. In the Core country, however, the capacity to innovate is negatively related to dynamism in the sector. Similarly, the minimum efficient size (MES) has a different coefficient. On the one hand, we observe a positive significant coefficient for firms in the Core country while the sign becomes negative for the Mediterranean countries.

This result highlights the different nature of the sectors and market competition. While sectors with higher average productivities show a positive association with the probability of innovating, innovative firms show more innovation difficulties in sectors which are dominated by large-scale firms. Finally, the sectoral productivity shows a negative impact on the probability of innovating, which is significant only for the Core country.

Hence, our results provide a clear indication that there is a statistically significant difference between country groups with regard to their own R&D and innovation behaviour. This is in line with the sectoral differences at a country level.

Regarding the relationship between innovation and the probability of becoming an HGF, our results suggest significant differences between country groups in line with Segarra-Blasco et al., (2016).

First, we observe that technological and non-technological innovations are not decisive determinants. Mainly, firms located in the technological frontier of Core country and Mediterranean countries seem to rely more on technological innovations and non-technological innovation, respectively. In contrast, in New EU countries, innovation outputs do not influence the probability of becoming an HGF.

Second, our results confirm previous empirical evidence on the negative relationship between firm size and the probability of being an HGF. Hence, small firms have a larger propensity to become an HGF in countries that have been incorporated in the EU project for many years.

Third, in Mediterranean and New EU member countries, those firms that belong to a group also show a positive association with the likelihood of becoming an HGF. However, the group variable does not influence HGF for the Core cluster.

Fourth, the export activity has relevant differences between the country clusters. Although a negative relationship with being an HGF is found for Core and Mediterranean countries, international activity is positive and significant for Mediterranean firms. In contrast, for New member firms, our results confirm the existing

literature that shows firms with international activity are more likely to be an HGF.[9] In line with these results, Du and Temouri (2015)the literature so far does not adequately explore the link between HGFs and productivity. This paper investigates the empirical link between total factor productivity (TFP and Mason & Brown, 2010) observe that HGFs are characterized by a larger internationalization and integration in global value chains.

Concerning the aggregate determinants, the variables are only significant for the New EU countries. First, we only observe a positive impact of MES on the probability of becoming an HGF for New EU members. This result highlights that these countries have systemic barriers to foster the growth of the firms in the domestic market. Hence, firms in sectors with a larger size have a higher capacity to innovate. Finally, sectoral productivity shows a negative coefficient on the probability of innovating. This implies that the capacity to introduce innovations is closely related to the productivity gap that may exist in these countries.

Given these relationships, the results clearly confirm our conjecture that HGFs are different for country groups that have been recently incorporated into the EU project than for countries that have been incorporated for many years. While success in innovation is closely related to previous investments in R&D and public funds in all countries, being an HGF is associated with innovative activity at firm level only in Core and Mediterranean countries (not in New member countries). HGFs in transition countries are seen to differ somewhat from those near the technological frontier because of issues such as being part of a group, undertaking an international activity, or having suitable partners within an enterprise group.

CONCLUSIONS

This paper began with the proposition that the enlargement of the EU due to Eastern European country membership has modified the current balance in the EU. During this process, the Innovation System in these New EU countries has diversified intensively. In line with other studies that examine the differences in innovation drivers, our results show that there is a direct link between R&D, innovation and firm growth in Core and Mediterranean countries (Krammer, 2009; Mohnen et al., 2006); however, New EU member countries have a weak connection between R&D, innovation, and firm growth. In Eastern countries, institutions such as universities, FDI, and the progress of institutional governance all play a crucial role promoting innovation and firm growth.

By applying a bivariate probit regression model, we analyse the propensity to innovate and the capacity to become an HGF in three different groups of countries (Core, Mediterranean, and New EU members) at firm level. First, we observed substantial heterogeneity between countries, which is the result of their very dif-

[9] Note that our data does not have temporal lags, so we are not capturing a causal relationship.

ferent contexts. Second, firms' dynamics in terms of growth are explained by different determinants such as the institutional context and the relative position of the countries in relation to the other economies. When the countries are near the technological frontier, product and process innovations foster the probability of becoming an HGF, while non-technological innovation appears as a major driver in Mediterranean countries. Lastly, individual firm's characteristics and export intensity play key roles in New EU countries.

One of the main conclusions is that during the period 2008–2010, firms in New EU countries invested and cooperated less in R&D and, consequently, they had less capacity to generate innovations than the other members. Paradoxically, Eastern European countries have more HGFs than countries from the Core or Mediterranean clusters. In fact, firms in Eastern European countries are more sensitive to R&D investment. Additionally, the fact that they belong to a group of companies, their foreign-market orientation, and the sectoral minimum efficient size are factors that affect their probability of becoming an HGF.

Over recent years, as some authors have highlighted (Audretsch et al., 2014; Brown & Mawson, 2016; Daunfeldt et al., 2016) the link between firm growth, R&D investment, and high-tech sectors was made on misconceived preconceptions. In countries that are close to the technological frontier, with robust systems of science and innovation, R&D plays a central role and there is a stronger link between R&D, innovation output, productivity, and firm growth. However, in countries with weak National Innovation Systems, such as Spain, this link is weaker and needs to be reinforced with more effective public policies. Consequently, the Mediterranean countries are suffering from the constraints of the current economic crisis and their lack of innovative capabilities. Eastern European countries, however, require a set of stable actions facilitating greater connection between universities, technological centres, and innovative firms in order to consolidate a National Innovation System that eliminates the isolated position of innovative firms that aspire to grow through R&D investment.

Since 2004, the enlargement of the EU has seen the addition of thirteen new countries most of which were satellites of the USSR until the 1990s. The transformation experienced by the EU has been considerable, but are the EU countries ready for the consequences? New EU members are completely different in economic, social, and institutional terms. Since joining, New EU members have experienced a high flow of direct foreign investment and considerable growth in trade flows. As we have continuously emphasized, the traditional North-South balance has led to a more unstable territorial balance, which has been to the detriment of the Mediterranean countries.

Focusing on the individual and environmental factors that affect manufacturing firms' ability to become HGFs, we found that drivers differ considerably between European countries. In Core countries, technological innovations emerge as crucial drivers to foster a firm's capacity to become an HGF. Conversely, non-techno-

logical innovations are the major driver for the Mediterranean members while, for the New EU members, exports appear as a key force in promoting a firm's capacity to become an HGF. These results highlight the need to develop a less monolithic industrial policy than the traditional recommendations offered by European institutions. The traditional industrial policy applied in the EU must be more sensitive to the specific context of each country and industrial sector. In summary, the policy of fostering innovation in Europe should not be considered homogeneous, but must be coordinated with actions undertaken by the governments and public agencies in each country.

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APPENDIX

Table A.1. Variable definitions

Dependent variables	
HGF	Dummy variable which takes the value 1 if the firm becomes an HGF measured in sales and 0 if not. Firm growth measured in log terms of sales between 2008 and 2010.
Innovative	Dummy variable which takes the value 1 if the firm has introduced technological innovations or non-technological innovations and 0 if not.
Independent variables	
Innovation sources	
intRD	Dummy variable which takes the value 1 if the firm invests in internal R&D and 0 if not.
extRD	Dummy variable which takes the value 1 if the firm invests in external R&D and 0 if not.
Cooperation	Dummy variable that takes a value equal to 1 if the firm cooperates with other agents and 0 if not.
Cooperation partners	
Internal cooperation	Dummy variable which takes the value 1 if firm cooperates with other firms within the enterprise group and 0 if not.
Market cooperation	Dummy variable which takes the value 1 if firm cooperates with suppliers, clients, competitors or private R&D institutions and 0 if not.
Institutional cooperation	Dummy variable which takes the value 1 if firm cooperates with universities, public research organizations or technology centres and 0 if not.
Innovation output	
TechInnovation	Dummy variable which takes the value 1 if the firm has introduced product or process innovations and 0 if not.
Non-techInnovation	Dummy variable which takes the value 1 if the firm has introduced marketing or organizational innovations t and 0 if not.

(Continued)

Table A.1. Variable definitions (*continuation*)

Individual characteristics	
Size	Size of dummy variables according to the firm's number of employees. Categories are: <49 employees, 50–249 employees and 250 or more employees. Note: In the CIS 2010 questionnaire, Croatian and Slovenian firms are only classified by two group sizes: less than 50 employees and 50 or more. more employees.
Group	Dummy variable that takes a value equal to 1 if the firm belongs to a group; 0 if not.
Regional public funds	Dummy variable that takes a value equal to 1 if the firm receives public financial support for innovation activities from local or regional authorities and 0 if not.
National public funds	Dummy variable that takes a value equal to 1 if the firm receives public financial support for innovation activities from central government and 0 if not.
EU public funds	Dummy variable that takes a value equal to 1 if the firm receives public financial support for innovation activities from the EU and 0 if not.
Export	Dummy variable that takes a value equal to 1 if the firm sells goods or services in other European Countries or all other countries and 0 if not.
Aggregate determinants	
Sectoral value added	Rate of change in value added at factor cost by sector. In the form of three-year averages over the 2008–2010 period.
MES	Minimum efficient size measures the relationship between the number of employees in sector x and the total number of firms in sector x in three-year averages over the 2008–2010 period.
Sectoral productivity	The natural logarithm of turnover per person employed by sectors in three-year averages over the 2008–2010 period.
Industry	Set of industry dummies according to the firm's main CIS business activities (NACE 2-digit level, Divisions 10-33).
Country	Set of country dummies belonging to Core country group, Mediterranean country group, and New EU members country group.

Table A.2.
Correlation matrix

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
1.HGF	1.000								
2.Innovative	-0.027*	1.000							
3.intRD	-0.024*	0.501*	1.000						
4.extRD	-0.009	0.339*	0.516*	1.000					
5.Cooperation	-0.003	0.378*	0.499*	0.491*	1.000				
6.Internal coop.	-0.004	0.218*	0.307*	0.347*	0.563*	1.000			
7.Market coop.	-0.003	0.339*	0.449*	0.435*	0.886*	0.512*	1.000		
8.Institutional coop.	-0.009	0.273*	0.432*	0.454*	0.726*	0.432*	0.609*	1.000	
9.TechInnovation	-0.028*	0.817*	0.593*	0.402*	0.451*	0.263*	0.404*	0.326*	1.000
10.Non-TechInnovation	-0.005	0.718*	0.395*	0.276*	0.321*	0.217*	0.312*	0.254*	0.453*
11.Size	0.002	0.240*	0.268*	0.252*	0.249*	0.265*	0.215*	0.207*	0.249*
12.Group	0.006	0.237*	0.258*	0.266*	0.267*	0.388*	0.229*	0.202*	0.249*
13.Regional funds	-0.010*	0.207*	0.291*	0.262*	0.251*	0.107*	0.199*	0.264*	0.245*
14.National funds	-0.009	0.277*	0.423*	0.381*	0.408*	0.228*	0.368*	0.409*	0.334*
15.EU funds	0.008	0.168*	0.216*	0.222*	0.267*	0.154*	0.251*	0.257*	0.202*
16.Exports	-0.006	0.276*	0.279*	0.205*	0.224*	0.152*	0.200*	0.186*	0.280*
17.Sectoral value added	0.027*	-0.023*	-0.019*	-0.002	-0.001	0.011*	-0.001	0.004	-0.019*
18.MES	0.041*	0.083*	0.134*	0.117*	0.098*	0.077*	0.062*	0.083*	0.093*
19.Sectoral productivity	-0.074*	0.230*	0.243*	0.171*	0.136*	0.074*	0.101*	0.134*	0.245*

(Continued)

Table A.2.
Correlation matrix (*continuation*)

	(10)	**(11)**	**(12)**	**(13)**	**(14)**	**(15)**	**(16)**	**(17)**	**(18)**
1.HGF									
2.Innovative									
3.intRD									
4.extRD									
5.Cooperation									
6.Internal coop.									
7.Market coop.									
8.Institutional coop.									
9.TechInnovation									
10.Non-TechInnovation	1.000								
11.Size	0.195*	1.000							
12.Group	0.182*	-0.403*	1.000						
13.Regional funds	0.141*	-0.042*	0.077*	1.000					
14.National funds	0.218*	-0.140*	0.156*	0.245*	1.000				
15.EU funds	0.140*	-0.098*	0.079*	0.111*	0.278*	1.000			
16.Exports	0.231*	-0.323*	0.265*	0.111*	0.176*	0.109*	1.000		
17.Sectoral value added	-0.017*	0.009	0.009	-0.048*	-0.018*	0.030*	-0.052*	1.000	
18.MES	0.048*	-0.155*	0.142*	0.042*	0.059*	0.051*	0.064*	0.164*	1.000
19.Sectoral productivity	0.143*	-0.037*	0.139*	0.179*	0.131*	0.011*	0.071*	-0.001	0.174*

* Significance at 5%
Source: Authors´ own calculations based on CIS2010, Eurostat.

ARTÍCULO

HIGH-GROWTH FIRMS IN PERU

Alex Coad
Gregory Scott

Coad, A., & Scott, G. (2018). High-growth firms in Peru. *Cuadernos de Economía*, *37*(75), 671-696.

This exploratory research note investigates the frequency and activity of High-Growth Firms (HGFs) in Peru using panel data on Peru's largest firms for the years 2001-2016. Firms in our dataset enjoyed strong growth in revenues during the period. Compared to other countries, HGFs are relatively common in Peru although the share they represent of all firms in the database decreased over the time span of our analysis. We confirm several previous findings, such as the heavy-tailed growth rates distribution, and the superior growth performance of small and young firms.

Keywords: High-Growth Firms, Firm Growth, Peru, Gibrat's Law.
JEL: L20, L25.

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We are grateful to Sergio Chión, Luis Felipe Zegarra, and seminar participants at CENTRUM Católica Graduate Business School (Lima) as well as the editor and an anonymous reviewer. Any remaining errors are ours alone

Sugerencia de citación: Coad, A., & Scott, G. (2018). High-growth firms in Peru. *Cuadernos de Economía, 37*(75), 671-696. doi: 10.15446/cuad.econ.v37n75.69585

Este artículo fue recibido el 25 de diciembre de 2017, ajustado el 15 de mayo de 2018, y su publicación aprobada el 16 de mayo de 2018.

Coad, A., & Scott, G. (2018). Empresas de alto crecimiento en Perú. *Cuadernos de Economía*, 37(75), 671-696.

Este artículo examina la frecuencia y actividad de las empresas de alto crecimiento en Perú, empleando datos de panel sobre las empresas más grandes de Perú entre los años 2001 y 2016. Las empresas de nuestro conjunto de datos gozaron de un fuerte crecimiento en sus ingresos durante dicho periodo. En comparación con otros países, las empresas de alto crecimiento son relativamente comunes en Perú, aunque la proporción que representan del total de empresas incluidas en la base de datos disminuyó con el paso del tiempo en el periodo analizado. Confirmamos varios hallazgos previos, como la distribución de cola pesada de las tasas de crecimiento, y el desempeño superior de crecimiento de las empresas pequeñas y jóvenes.

Palabras clave: Empresas de alto crecimiento, crecimiento empresarial, Perú, Ley de Gibrat.
JEL: L20, L25.

Coad, A., & Scott, G. (2018). Entreprises à forte croissance au Pérou. *Cuadernos de Economía*, 37(75), 671-696.

Cet article examine la fréquence et l'activité des entreprises à forte croissance au Pérou, en utilisant des données de panel sur les entreprises les plus grandes de ce pays entre les années 2001 et 2016. Les entreprises de notre ensemble de données ont connu une forte croissance de leurs revenus au cours de cette période. Comparativement à d'autres pays, les entreprises à forte croissance sont relativement communes au Pérou bien que la proportion qu'elles représentent par rapport au total des entreprises inclues dans la base de données ait diminué au cours de la période analysée. Nous confirmons plusieurs découvertes antérieures, comme la distribution de queue lourde des taux de croissance, et une croissance plus dynamique des petites et jeunes entreprises.

Mots-clés: entreprises à forte croissance, croissance entrepreneuriale, Pérou, Loi de Gibrat.
JEL: L20, L25.

Coad, A., & Scott, G. (2018). Empresas de alto crescimento no Peru. *Cuadernos de Economía*, 37(75), 671-696.

Este artigo examina a frequência e a atividade das empresas de alto crescimento no Peru, usando dados em painel sobre as principais empresas no Peru entre 2001 e 2016. As empresas em nosso conjunto de dados tiveram um forte crescimento em suas receitas durante esse período. As empresas em nosso conjunto de dados tiveram um forte crescimento em suas receitas durante esse período. Em comparação com outros países, as empresas de alto crescimento são relativamente comuns no Peru, embora a proporção que elas representam do número total de empresas incluídas no banco de dados tenha diminuído ao longo do tempo no período analisado. Confirmamos várias descobertas anteriores, como a distribuição de cauda pesada das taxas de crescimento e o desempenho de crescimento superior de empresas pequenas e jovens.

Palavras-chave: empresas de alto crescimento, crescimento empresarial, Peru, Lei de Gibrat.
JEL: L20, L25.

INTRODUCTION

Entrepreneurship has long been recognized as a key driver of innovation and economic development (Schumpeter, 1934; Audretsch, 2012). Renewed interest in an understanding of micro-macro linkages between firm-level activities and their collective impact at the national level have taken on heightened importance of late in part because of the global recession of 2008-2009 that affected both industrial and developing countries alike, with devastating effects on income, employment, and growth. In that context, academics and policymakers have become increasingly aware that it is not the quantity of firms that matters for economic performance, but the quality of these firms (Henrekson & Sanandaji, 2014; Acs, Åstebro, Audretsch, & Robinson, 2016; Lederman, Messina, Pienknagura, & Rigolinia, 2014). In particular, as noted earlier, a small number of firms can account for a disproportionately large share of job creation (Birch, 1979). And, as has been seen with the advent of the internet, a few of such enterprises can also contribute to the emergence of new sectors (Bos & Stam, 2014; OECD, 2015) and provide jobs for individuals who might otherwise be marginalized on the labour market (Coad, Daunfeldt, Johansson, & Wennberg, 2014a). This coincidence of circumstances and events has led to growing interest in High-Growth Firms (HGFs) (Delmar, Davidsson, & Gartner, 2003; Henrekson, & Johansson, 2010; Coad, Daunfeldt, Hölzl, Johansson, & Nightingale, 2014; Bianchini, Bottazzi, & Tamagni 2017; Demir, Wennberg, & McKelvie, 2017). In particular, international organizations such as the European Commission and the OECD are increasingly interested in macroeconomic indicators, at the national level, regarding the frequencies of high-growth firms (Eurostat-OECD, 2007; European Commission, 2014). However, most of the research and discussion on HGFs has been focused on industrialized countries, e.g. (Henrekson & Johansson, 2010; OECD, 2011; Coad et al., 2014b) even as developing countries increasingly recognize the importance of the issues associated with such enterprises (Navarro, Benavente, & Crespi, 2016; OECD, 2016, McKenzie, 2017).

In light of these various considerations, this exploratory research note contributes to the literature by presenting novel findings on HGFs in Peru. Given its recovery from macroeconomic instability in the 1970s, 1980s, and 1990s (Tello & Tavara, 2010), as well as the challenges inherent in a dichotomous business sector much of which remains mired in informality (Schneider, Buehn, & Montenegro, 2010; Machado, 2014), Peru constitutes an interesting case for entrepreneurship research. More specifically, a series of recent studies of entrepreneurship, innovation, and growth in company sales in Peru – many of which were focused on a particular point in time – reaffirm the appropriateness of a firm-level analysis over a more sustained period (Chaston & Scott, 2012; Scott & Chaston, 2012, 2013, 2014). In a similar vein, other recent research that focused on the evolution of firms in particular sectors points to the usefulness of a broader approach aimed at understanding the performance of firms across the entire economy (Llosa & Panizza, 2015; Tello, 2017). Furthermore, based on available data for other countries and Peru´s recent record of rapid economic growth (World Bank, 2017), prelimi-

nary findings suggest that Peru may well have had a relatively high share of HGFs in recent years. This study then seeks to explore the incidence, duration and characterization of HGFs in Peru during the period 2001-2016 both to inform private sector participants regarding recent firm performance and to provide added empirical evidence to the on-going policy debate related to innovation and entrepreneurship (OECD, 2016).

This paper is organized as follows: Section 2 contains a brief overview of the Peruvian economy during previous decades so as to better contextualize the current analysis. Section 3 presents the data utilized for this study followed by the analysis in Section 4. Section 5 provides some concluding remarks and identifies a number of emerging issues for future research.

BACKGROUND ON THE PERUVIAN ECONOMY

Recent estimates indicate the GDP of Peru was 403 billion in PPP Intl$ (international dollars), and its GDP per capita was Intl$ 12,639[1], below that of its neighbours Chile (24,170), Brazil (15,941), and Colombia (14,164), but above that of its neighbours Ecuador (11,839) and Bolivia (6,530). Peru is currently preparing to join the OECD (Organization of Economic Co-operation and Development) (CGBS, 2016), perhaps as early as 2021.[2] Peru´s current economic indicators belie the outcome of a tumultuous and violent journey through economic, political, and social turmoil during the 1970s, 1980s, and early 1990s characterized by four drastically different governments in succession that had a major impact on firm survival, let alone the potential for firm growth. A brief review of these past developments is intended to put our analysis of firm performance in the more recent period under review in proper context and, thereby, to facilitate a more grounded interpretation of associated statistical analysis.

A leftist military regime throughout the 1970s sought to give the State control over economic activities by confiscating foreign and domestic companies alike (Dancourt, Mendoza, & Vilcapoma, 1997; Flores & Ickis, 2007) while drastically curtailing civil liberties (e.g., freedom of speech, freedom of the press) in the process (Quiroz, 2008). By the late 1970s, sharply deteriorating real incomes due to economic mismanagement, graft, and corruption forced a return to civilian rule in 1980 (Skidmore & Smith, 1997).

From 1980-1985, the democratically elected government fostered a policy of import substitution that favoured certain firms and sectors for domestic capitalist development while maintaining State enterprises and encouraging foreign direct

[1] PPP in millions, according to IMF estimates in the April 2015 World Economic Outlook database. See https://en.wikipedia.org/wiki/List_of_Latin_American_and_Caribbean_countries_by_GDP_(PPP).

[2] See http://www.andina.com.pe/ingles/noticia-oecd-peru-likely-to-join-group-of-developed-countries-by-2021-603267.aspx

investment in others e.g., mining (Kasturi, Barton, & Reficco, 2012). High interest rates on an inherited foreign debt, the El Niño natural disaster of 1983, and a public sector without a significant tax base all contributed to an inflation rate of 150% a year in 1985, and a sharp drop in per capita incomes and also the prospects for firm growth based on domestic demand in the process (Dancourt, Mendoza, & Vilcapoma, 1997). Adding to the already challenging convergence of circumstances, terrorism became emboldened through funding based on a major expansion in coca cultivation tied to production and shipment of illegal drugs (Gonzales de Olarte, 1991) and the absence of a coherent government strategy to suppress it (Murakami, 2007).

In 1985, Alan Garcia's newly elected government gained international attention by embracing economic heterodoxy – promising to reassert the role of the State in economic activity, e.g. by controlling prices for basic food commodities, only paying 10% of export earnings towards the foreign debt, and covering the subsequent fiscal deficit by printing money (Pastor & Wise, 1992; Rossini & Santos, 2015). The resulting hyperinflation reached over 7000% a year by 1990 driving many firms into bankruptcy as terrorist activity became much more widespread, eventually leading to nearly 70,000 civilian casualties (Loayza, 2008; World Bank 2017).

With the nation on the verge of bankruptcy and isolated from international capital markets, the Fujimori government embraced a greatly reduced role of the government in economic affairs and instead opted for a policy of globalization—aggressively seeking free trade agreements with various countries, privatization of State enterprises as a way of attracting much needed foreign direct investment, liberalization, i.e. the elimination of price controls on basic household commodities (e.g., food, fuel), and a freely floating exchange rate (Pasco-Font & Saavedra, 2001; Llosa and Panniza, 2015; Rossini & Santos, 2015). The counter terrorism strategy was also revamped by focusing on the leadership instead of fighting the rank and file. By the mid-1990s, the success of these policies led to a stabilization of the economy and the capture of many of the leading terrorists. As the economy opened up to much greater foreign competition in the domestic market for the first time in decades, many long-established firms were bought out, forced into mergers, or consolidated into larger enterprises given the pressures on their financial viability (Shimuzu, 2004). But the recession of 1997-98, brought in part by the crisis in Asia and a recurrence of El Niño, gave way to a series of revelations regarding massive corruption in government involving many prominent private firms and the eventual end of the Fujimori government (Conaghan, 2005; Abusada & Cusato, 2007).

Entering the new millennium, the combination of higher world prices for minerals and metals and successive governments' consistent embrace of privatisation and market liberalisation paved the way for year after year of rapid economic growth (Hausmann & Kingler, 2008; Anon, 2009; González Vigil, 2009). So much so that in the midst of the 2009 global recession, Peru was one of only a handful of countries world-wide that registered positive economic growth despite the major down-

turn in most Western economies (IMD, 2010) thereby enabling it to emerge as one of the strongest economies in Latin America (Tello & Tavara, 2010).

Abundant mineral resources have supported strong export performance, and, in recent years, growth has spread to other sectors of the economy including tourism, agribusiness, and construction. Peru has also witnessed a revival of domestic demand with rising real incomes stimulating greater food production for the internal market (De Althaus, 2007; Scott, 2011; Loayza, 2008) and a boom in both residential and commercial construction. Tourism continues to flourish, generating billions in revenue and numerous new jobs in hotels, transportation and the restaurant industry.

The succession of positive economic developments enabled Peru to enjoy a growth rate of 5.8% or more for each year during 2010-2013, although since then it has slowed down slightly, with 2.4% in 2014, 3.3% in 2015, and 4.1% in 2016.[3] Nonetheless, Peruvian exports remain heavily dependent on mining and agricultural products (World Bank, 2017). Moreover, the structure of the economy continues to be characterized by a small number of conglomerates made up of family-owned and controlled large firms (Shimizu, 2004; Conaghan, 2005) that are complemented by the presence of multinational enterprises in certain sectors (e.g., mining, energy, telecommunications, and retail trade) and a large number of informal enterprises that account for an estimated 35% - 60% of GDP and employ some 60% of the economically active workforce (Machado, 2014).

DATA DESCRIPTION

According to government statistics (INEI, 2017), some 2.1 million legally registered firms currently operate in Peru (Table 1), with perhaps another 2.1 million more informal enterprises based on available estimates of their share of GDP (Schneider, Buehn, & Montenegro, 2010). Over 94% of all these companies are micro-businesses. In that context, we analyse the Peru Top 10,000 dataset, which collects the annual statistics on the largest legally constituted firms; they are grouped in successive waves and joined together into a panel. Previous work on this dataset includes Shimizu (2006), Alarco Tosoni (2011) and Tello (2017).

We use the most complete available dataset: "Base Completa VIP."[4] Our data focuses on the largest firms in Peru; thus, small, young firms are under-represented. Having said that, it should be also be noted that a "large" firm in this dataset might best be understood as including some firms that would indeed be considered large in terms of revenues or numbers of employees, but given published statistics on all legal firms in Peru, a collection of the largest 10,000 firms is perhaps best understood as made up of firms that are the largest compared to all the

[3] See http://www.ptp.pe/pdf/macroptpdic2015.pdf

[4] Data exported on 9th August 2017. Information on the data is available at the following link: http://www.toponlineapp.com/toponline/index.php?r=bases/completavip

others, (it is certain to include medium-firms and possibly even some small firms). Be that as it may, our use of this dataset implies a potential source of sample selection bias, for example if small firms, which may have higher growth rates (Sutton, 1997), are not included in our analysis. This focus on the largest firms should be kept in mind when interpreting our results.

Table 1.
Peru: Companies, by Business Segment, 2015-16

Business Segment	2015	2016		Var %
		Absolute	Percentage	2016/15
Total	**2 042 992**	**2 124 280**	**100**	**4.0**
Microbusiness	1 933 525	2 011 153	94.7	4.0
Small Business	89 993	92 789	4.4	3.1
Large and medium business	12 494	13 031	0.6	4.3
Public Administration	6 980	7 307	0.3	4.7

Source: Instituto Nacional de Estadística e Informática (2017).

The database includes information on revenues as well as other firm characteristics such as age and sector of activity.[5] The panel stretches from 1993 to 2017 although data on revenues is only available for the years 2000-2016.[6]

Firms are identified by their 'RUC' ('Registro Único de Contribuyentes') identifier code, which is a national code used by tax authorities for statistical records of economic activity. In the raw data, the same RUC code may appear more than once in a year, in cases where the contact details of different individuals from the same firm are listed. We therefore drop duplicates by keeping only the first occurrence of each group of duplicated observations for each RUC code in each year. Our data cleaning also involves dropping possible cases of negative revenues.

Firm growth is usually measured in terms of total sales or employment (Shepherd & Wiklund, 2009). The employment variable seems problematic in our dataset,[7] so we focus on revenues ('*Ingresos*') growth. The growth rate of revenues, for firm

[5] There are also some financial variables (such as 'patrimonio' (equity) and 'ROE' (return on equity)), although these variables may not be entirely reliable. For example, ROE is recorded with a value of zero in over 90% of cases (345,805 out of 376,852), which probably does not mean that ROE was actually zero for these firms: rather, ROE was missing.

[6] In some cases, variables are available for more recent years although these are projections rather than actual values. In our analysis, we focus only on observed values and not projections.

[7] The employment variable has many missing observations: many firms are recorded as having only 1 employee (which is unexpected in a sample of Peru's largest firms), and there is precisely zero variation in number of employees across the years in our sample. Given that we have no reliable variable for employment, we cannot construct an indicator for productivity in our dataset.

i in year *t*, is calculated by taking log-differences of annual revenues (Tornqvist, Vartia, & Vartia, 1985; Coad, 2009).

$$\text{Gr\_revenues}_{it} = \log(\text{revenues})_{it} - \log(\text{revenues})_{i,t-1}$$

Age is calculated with reference to the year of founding.[8] Cases of negative age, which are sometimes observed in the early years of the panel, are implicitly dropped from the analysis by taking the logarithm of age in the regressions. A variable 'estatal' provides information on whether a firm is a State-owned enterprise, but it does not distinguish between non-State-owned enterprises, and missing observations (the variable only takes the value 1 or missing; and we convert all missing observations to zeroes to create a dummy). Therefore, this variable for State-owned firms should be interpreted with caution.

Deflating the data

Our focus on revenue growth rather than employment growth requires that we deflate our data to address inflation. This is an important methodological step to avoid confounding inflation with genuine firm growth. This is especially important in the Peruvian context, because Peru suffered inflation of over 50% for every year between 1981 and 1992, with over 7000% inflation in 1990 (Loayza, 2008; Rossini & Santos, 2015). However, inflation has remained below 10% from 1996 onwards.

To control for inflation, ideally we would use accurate sector-specific deflators to account for possible differences across sectors – however, we did not find any such deflator. Therefore we use the GDP deflator (annual %) from the World Development Indicators of the World Bank national accounts data, and OECD National Accounts data files (indicator code: NY.GDP.DEFL.KD.ZG; downloaded from https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG , last updated 14th December 2017). To be precise, "Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency."[9]

ANALYSIS

Descriptives

Table 2 contains some summary statistics for our data. Figure 1 shows the firm size distribution, for different years. Firm size has been increasing over years, as the

[8] To be precise, the year of foundation was extracted from the information on day of foundation, and this is subtracted from the current year for each observation.

[9] See https://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG

distribution shifts to the right. Since 2000, the distribution has a narrower support - there is a lower proportion of relatively smaller firms in our dataset in later years.

Table 2
Summary Statistics for Firms with Positive Revenues

Variable	mean	sd	p10	p25	p50	p75	p90	N
Revenues (millions)	87.94	550.72	4.18	8.39	15.56	40.96	129.22	91833
Growth of revenues	0.08	0.65	-0.30	-0.08	0.07	0.23	0.49	69489
No. of branches	3.31	18.93	1	1	1	1	2	91032
Age	19.46	18.26	4	8	14	24	44	91721
Importer dummy	0.45	0.50	0	0	0	1	1	91833
Exporter dummy	0.22	0.41	0	0	0	0	1	91833
State-owned	0.10	0.30	0	0	0	0	1	91833

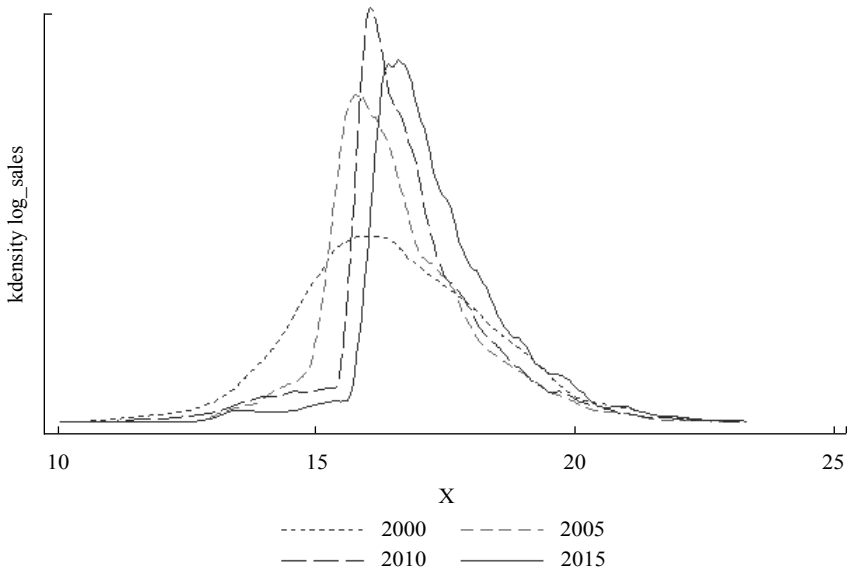
Source: Our calculations.

Figure 2 shows the growth rates distribution for firms in our sample. In contrast to previous work for other countries (e.g. Stanley et al., 1996 for the US; Bottazzi & Secchi, 2006 for Italy; Bottazzi, Coad, Jacoby & Secchi, 2011 for France), the growth rates distribution is not symmetric, but rapid growth is relatively common, and (especially in 2005) rapid decline is relatively rare. The large firms in our sample appear to be surging forward in terms of rapid revenues growth.

Figure 3 shows the evolution of the first four moments of the growth rate distribution throughout the years. As Peru pulled out of the 1990s crisis, one could have expected a period of high growth, and perhaps decreasing business volatility. Figure 3 complements Figure 2, and shows that the mean growth rate has usually been above zero, corresponding to positive revenues growth, and also that – apart from a few peaks – the standard deviation of growth rates seems to have remained fairly flat. The skewness errs on the positive side, which suggests that the growth rate distribution is asymmetric, with a larger weight at the right tail (i.e. there are more firms enjoying large positive growth rates than large negative ones).

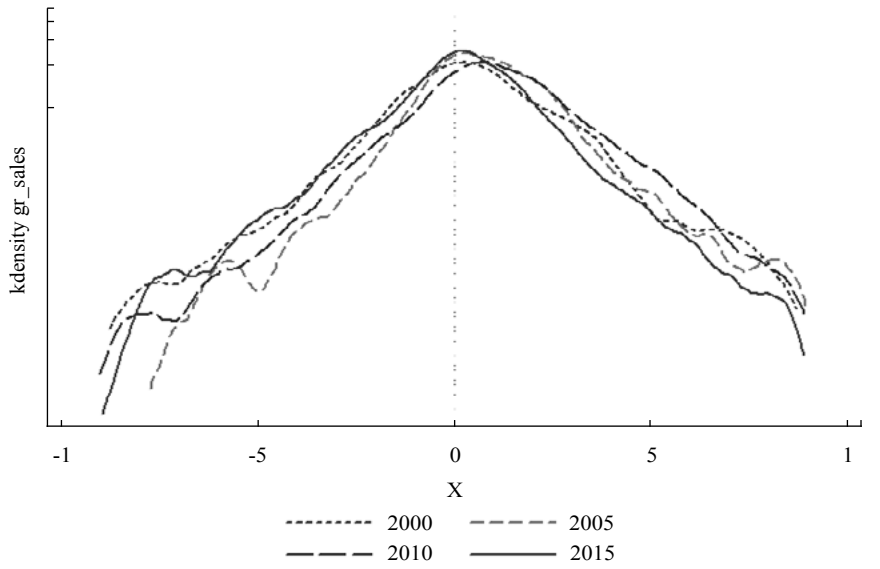
Figure 4 shows the bivariate density of growth rates in consecutive years, following Coad, Daunfeldt, & Halvarsson, (2018). The area that has the highest density (i.e. the area with the darkest shading) corresponds to mild-positive growth rates in t-1 and also t. However, all possible combinations of growth are observed (including the possibility of decline in two consecutive years, which would correspond to the bottom left quadrant).

Figure 1.
Firm Size Distribution (Where Size is Measured in Terms of log of Revenues), for Different Years.



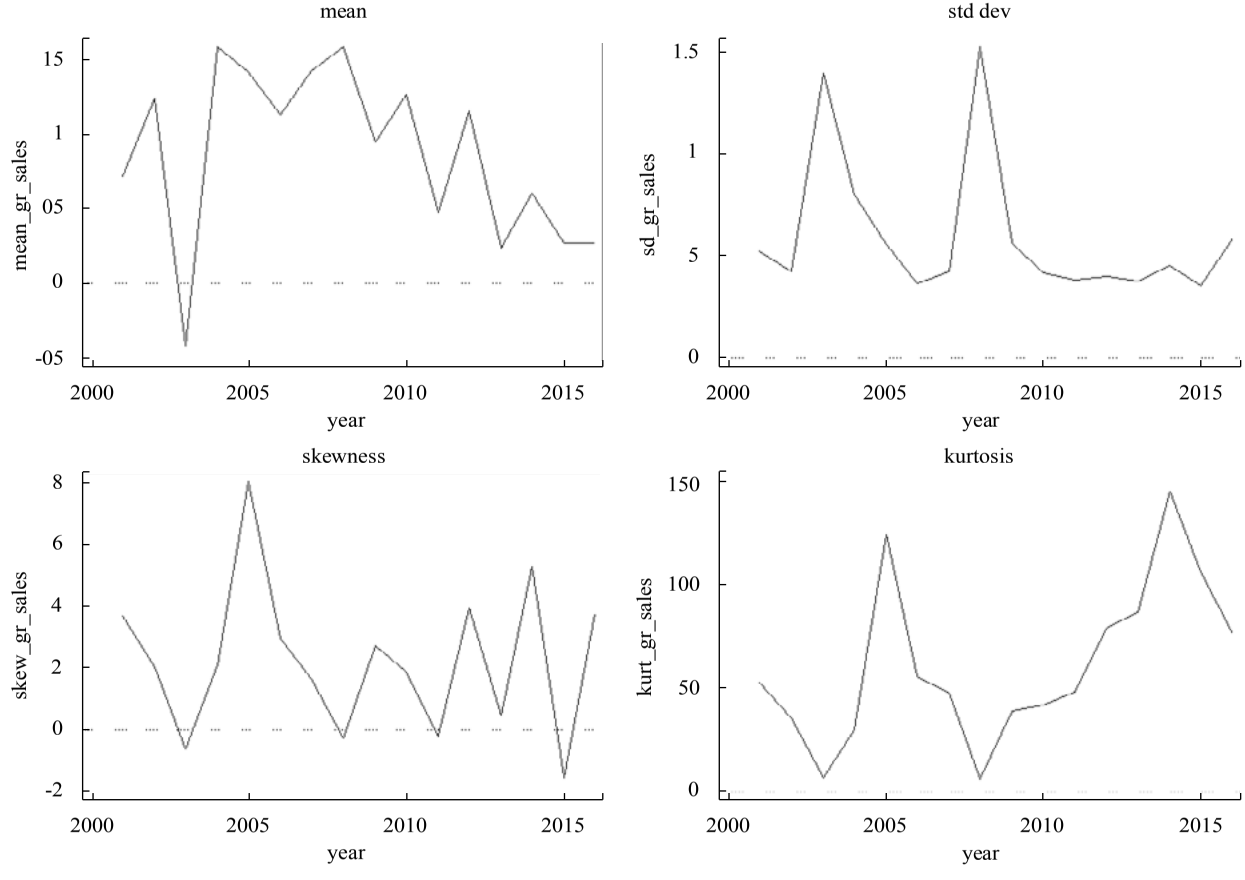
Source: Our calculations.

Figure 2.
Growth Rates Distribution for Our Dataset, for Different Years. Note the log scale on the y-axis. The dotted line is at growth=0.0000.



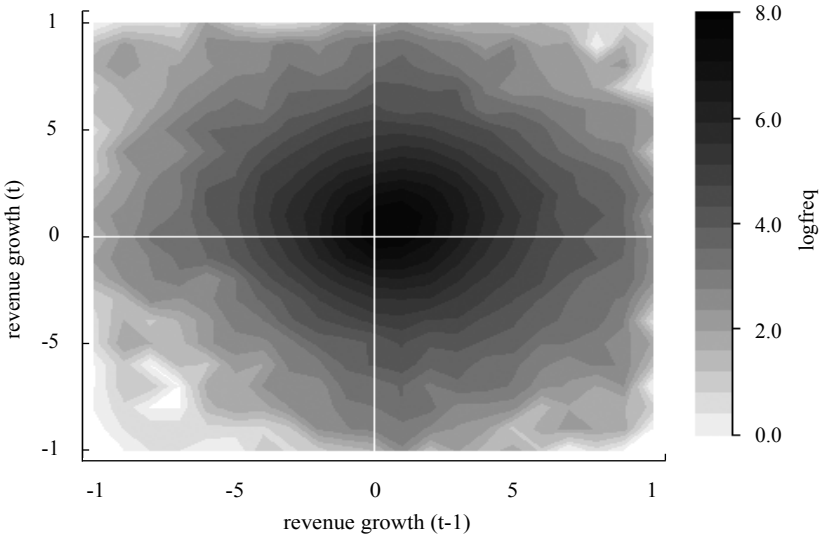
Source: Our calculations.

Figure 3.
Evolution of the 4 Moments of the Growth Rate Distribution Over Years.



Source: Our calculations.

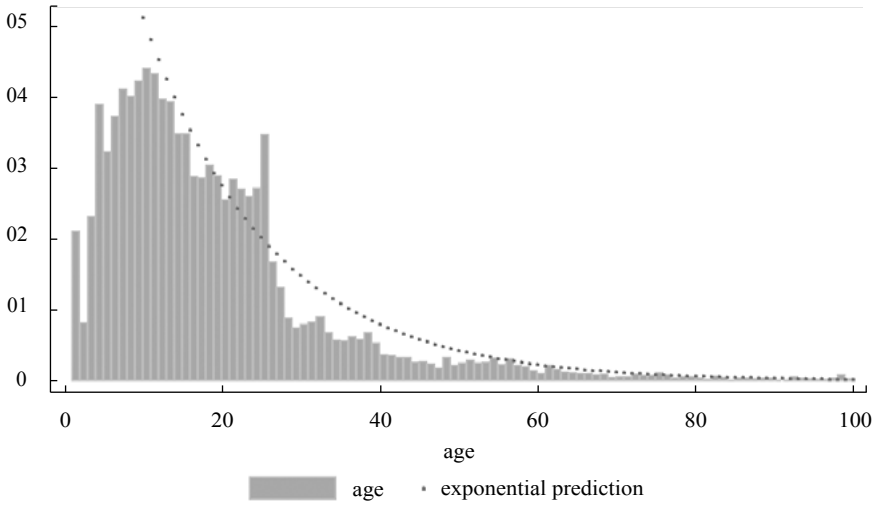
Figure 4.
Contour Plot of Revenue Growth in Consecutive Periods. All Years Pooled Together



Note: Colouring shades correspond to the frequency of the number of firms that have been categorized into logarithmic bins. White areas contain no observations without interpolation. The contour is delimited to growth rates ±1.

Source: Our calculations.

Figure 5.
Age distribution with reference to the year 2018, for ages up to 100. Firms aged over 100 are not plotted here. The fitted exponential distribution, which serves as an approximate visual aid, is inserted manually using OLS predicted values of (log of) number of firms of each age, for firms in the range 10-100 years.



Source: Our calculations.

Figure 5 shows the age distribution of firms in our sample. The majority of firms are relatively young, in the sense that they are less than thirty years old. Some firms are older than 100. To the extent that the true age distribution is exponential (Coad, 2010), or perhaps Weibull-distributed (Axtell, 2016), the fact that the mode of the age distribution occurs at age around ten suggests that firms aged less than ten years are under-represented in our dataset. An exponential fit is plotted alongside the empirical density, fitted for the range of firms that are ten or older, (because the mode is at around ten years) and for ages up to 100. Compared to the exponential fit, the empirical density has a relatively large number of firms aged in their early twenties (i.e. born in the 1990s), but, with a few notable exceptions (Marquina, 2010; Lavardo Gagliardi, 2013; Paan, 2013), relatively few firms in their thirties (i.e. relatively few born in the 1980s).

Analysis of HGFs

Descriptives of HGFs

The OECD-Eurostat definition of a High-Growth Firm refers to an average of 20% annual growth over a three-year period (Eurostat-OECD, 2007), i.e.:

$$\left(\frac{X_t}{X_{(t-3)}} \right) 1/3 - 1 \geq 0.20$$

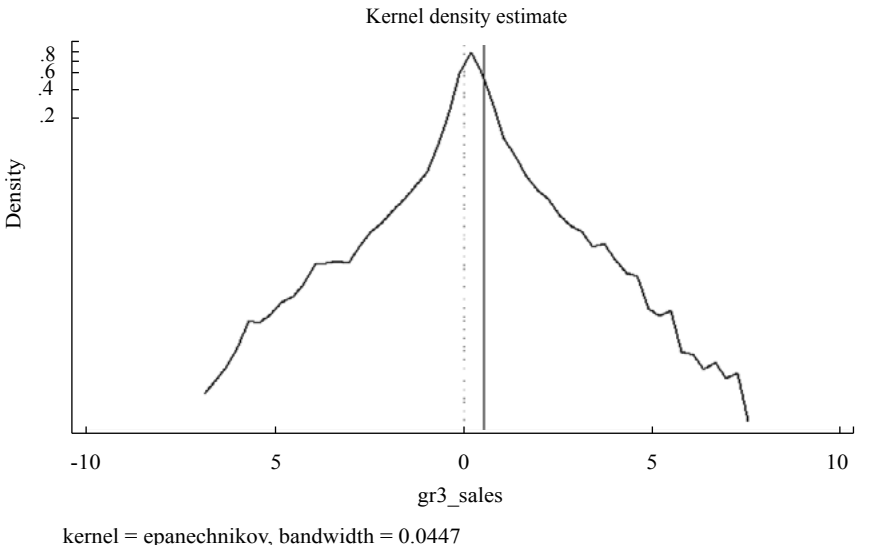
where X is the size of the firm in year t.[10] Some previous investigations into high-growth firms have thus often measured growth over a three-year period (Hölzl, 2014, Zhou, De Kok, Hartog, & Van Der Zwan, 2012; Daunfeldt, Johansen, & Halvarsson, 2015; Choi, Rupasingha, Robertson, & Leigh, 2017). Figure 6 presents the distribution of growth rates over a three year period, and illustrates the threshold above which the OECD-Eurostat definition would classify a firm as an HGF. Many firms in our sample have growth rates above this threshold.

HGFs by Sector

Are HGFs more common in certain sectors than others? Despite the excitement about high-tech HGFs, nevertheless HGFs are not more common in high-tech sectors (Mason & Brown, 2013; Daunfeldt, Elert & Johansson, 2016) although the survey by Henrekson and Johansson (2010) finds that they are over-represented in services.

[10] A further condition is that the firm should have ten or more employees in the initial year (t-3) (Daunfeldt et al., 2015). Given that we have incomplete data on employment, we focus on sales growth and ignore the 10+ employees restriction: a restriction which, in any case, has been criticized by some authors (Daunfeldt et al., 2015).

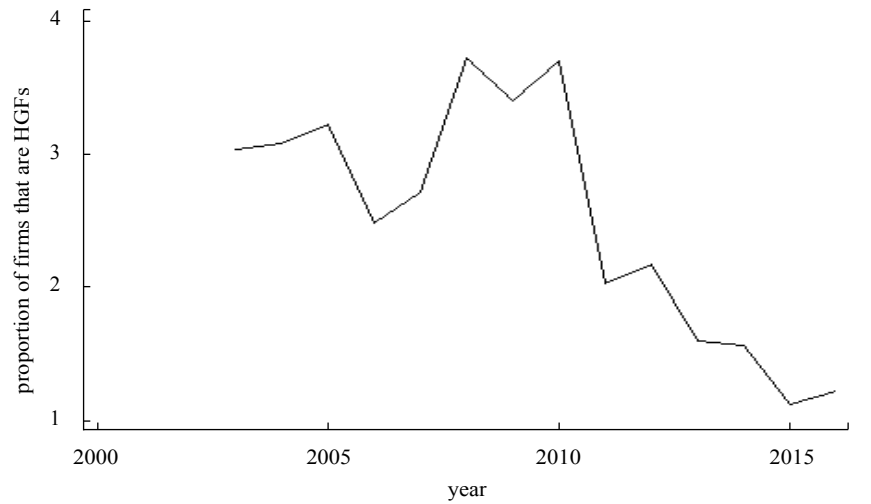
Figure 6.
Position of the threshold for being an HGF (solid line): growth (on average) of 20% each year over three years. The dotted line corresponds to growth = 0.000. All years pooled together.



Source: Our calculations.

Figure 7 shows that the number of HGFs has been decreasing in recent years. This could correspond to a slowing down of the Peruvian economy after the boom during the first decade of the 2000s.

Figure 7.
Proportion of HGFs in Each Year.



Source: Our calculations.

Table A1 (in the Appendix) shows the proportions of HGFs in each sector. To avoid the 'law of small numbers' statistical fallacy (Kahneman, 2011, Chapter 10), we focus on sectors with a larger number of firms.[11] Similar to Choi et al. (2017), we find a large share of HGFs in the construction sector. HGFs are also particularly common in public administration, 'other services', mining, finance, consultancy and services, real estate, and the agro-industrial and farming sector. HGFs are conspicuously less common in textiles, energy and water, printing, and law.

It should be remembered, though, that just because these sectors had a relatively large share of HGFs in the past, this is no guarantee that they will have many HGFs in future.

Comparing HGF numbers with Other Countries

How does the frequency of HGFs in Peru compare to other countries? Although we do not have access to microdata from other countries, nevertheless we can make use of some calculations reported by the OECD. In particular, we report the share of High-Growth Enterprises (turnover definition) of the SDBS Business Demography Indicators, for available years and countries.[12]

By international comparison, the Peruvian firms in our dataset have had an extraordinary growth performance (see Table 3). (Remember that our revenues data has already been deflated to remove inflation.) Compared to other countries, a relatively high share of them would qualify as HGFs. Other countries with high shares of HGFs are Latvia, Estonia and Bulgaria.

Regression Analysis on Growth

Our preceding non-parametric analysis is followed by some parametric regressions, which allow us to investigate the factors associated with growth and control for potentially confounding effects in a multivariate setting. We begin with logit regressions in Table 4, where the dependent variable is the firm's HGF status (taking values 1 for HGFs and 0 for non-HGFs). In Table 5, we focus on the factors associated with a firm's growth rate in an individual year, in an augmented Gibrat's law framework (Gibrat, 1931; Coad, 2009), to investigate the role of lagged size and other variables on the subsequent growth performance. Given that the growth rate distribution is not Gaussian, but displays a 'tent-shape' reminiscent of the Laplace distribution (see our Figure 2, and also Bottazzi et al., 2011), we prefer least absolute deviation (LAD) regression, also known as median regression, to the usual ordinary least squares (OLS) regression model.

[11]The 'law of small numbers' fallacy explains why extremely high or low frequencies are more likely to be found in groups with small populations. For example, it is more likely that someone will score 100% heads after flipping a coin three times than after flipping it a hundred times.

[12]See http://stats.oecd.org/, in particular: Industry and Services / Structural and Demographic Business Statistics / SDBS Business Demography Indicators / High-Growth Enterprises share (turnover definition).

Table 3.
Percentage of firms that are high-growth firms, where high growth is defined in terms of growth of (deflated) revenues.

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Peru	30.4	30.8	32.2	24.8	27.1	37.2	34.0	37.0	20.2	21.7	15.9	15.6	11.1	12.2
Canada			8.8	9.6	8.1									
Denmark			7.9	12	14.3									
Estonia			18.4	21.9	21.1									
Hungary			10.9	13.5	15.1									
Italy			5.2	8	8.9									
Latvia			23	27	34.1									
Norway			..	15.3	..									
Slovenia			11.5	12.8	13.8									
Sweden			..	11.8	14.5									
Bulgaria			17.5	22.3	..									
Romania			5.2	6.1	7.7									

Notes: Rate of High-Growth Enterprises (20% annual growth based on turnover), as a percentage. OECD data refer to Manufacturing, for firms with ten employees or more.

Source: Data for Peru comes from our TOP 10,000 dataset (deflated revenues growth). Data for other countries comes from the OECD SDBS Business Demography Indicators.

Table 4.
Logit Regression Results to Determine Which Firms are HGFs. Robust standard errors. Key to significance stars: *** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)
	logit HGF_revenues	**logit HGF_revenues**	**logit HGF_revenues**
VARIABLES	**HGF_revenues**	**HGF_revenues**	**HGF_revenues**
log_revenues (3rd lag)	-0.471***	-0.450***	-0.520***
	(0.0100)	(0.0101)	(0.0106)
log_age		-0.316***	-0.355***
		(0.0179)	(0.0181)
No. branches			0.00812***
			(0.000848)
Importer dummy			0.383***
			(0.0288)
Exporter dummy			0.384***
			(0.0324)
State			0.312***
			(0.0962)
Sector dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Constant	5.874***	6.427***	7.185***
	(0.204)	(0.207)	(0.212)
Observations	52,986	52,902	52,443
Pseudo-R2	0.1096	0.1156	0.1282

Source: Our calculations.

Table 4 shows that younger and smaller firms are more likely to be HGFs, in keeping with a wide range of other studies (Henrekson & Johansson, 2010). Firms that are importers and exporters are more likely to be HGFs. Similarly, Table 5 shows that younger and smaller firms have lower growth on average.

In Table 5, the slightly negative coefficient on lagged growth suggests that revenues growth has a negative autocorrelation. Firms that grew rapidly in one period are unlikely to repeat this performance in the following period.

Tables 4 and 5 also show that revenues growth is more likely (whether measured in terms of HGF status or in terms of the annual revenues growth rate) for firms that have more branch offices ('sucursales') and that are active on an international scale (in terms of importing and exporting activity). Also, State-owned firms are more likely to be HGFs (Table 4) and to have higher growth rates (column (4) of Table 5).

Table 5.

Median regression results (i.e. quantile regression at the 50% quantile), along with OLS and panel fixed-effect least-squares estimates. Standard errors are clustered at the firm level. Key to significance stars: *** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)	(5)
	LAD growth	**LAD growth**	**LAD growth**	**OLS growth**	**FE growth**
VARIABLES	**gr_revenues**	**gr_revenues**	**gr_revenues**	**gr_revenues**	**gr_revenues**
log_revenues (lagged)	-0.0215***	-0.0120***	-0.0173***	-0.0943***	-0.465***
	(0.000939)	(0.000856)	(0.00103)	(0.00350)	(0.00968)
gr_revenues (lagged)		-0.0209***	-0.0223***	-0.0733***	-0.000447
		(0.00289)	(0.00281)	(0.00831)	(0.00735)
log_age			-0.0170***	-0.0154***	0.0270
			(0.00168)	(0.00388)	(0.0285)
No. branches			0.000432***	0.00184***	
			(8.49e-05)	(0.000486)	
Importer dummy			0.0331***	0.0900***	
			(0.00280)	(0.00579)	
Exporter dummy			0.0207***	0.0787***	
			(0.00330)	(0.00666)	
State			0.0109	0.0803***	
			(0.00671)	(0.0254)	
Sector dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Constant	0.413***	0.321***	0.362***	1.645***	8.077***
	(0.0187)	(0.0179)	(0.0209)	(0.0579)	(0.194)
Observations	69,489	53,959	53,394	53,394	53,394
R-squared	0.036	0.025	0.036	0.075	0.267
Number of RUC					9,345

Source: Our calculations.

CONCLUSION

This research note presents an exploratory study of HGFs in an emerging economy context that has, until now, escaped attention: Peru. Firms in our dataset enjoyed a bullish growth in revenues during the period studied. HGFs are relatively common in Peru, compared to other countries, although their share has decreased over the time span of our analysis. We confirm several previous findings, such as the heavy-tailed growth rates distribution, and the superior growth performance of small and young firms.

Our sample focuses on relatively large firms, and undersamples young firms. Indeed, it is difficult to obtain data on small Peruvian firms, because many small-scale entrepreneurs in Peru prefer to remain informal (Scott & Zelada, 2011; Andersson & Waldenström, 2017), and, hence, are not visible to data collectors. Further work could investigate the growth performance of samples of younger and smaller firms in Peru if data becomes available.

Our findings on the strong growth performance of Peruvian firms leads to questions about the role of HGFs in economic growth and recoveries. Is economic growth like a rising tide that lifts the growth rates of all firms? Or, on the other hand, do HGFs bring about large-scale growth through some kind of 'multiplier effect'? Which is the most important direction of causality? Future work could more closely investigate the causal relation between frequency of HGFs and economic development.

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APPENDIX 1

Table A1.
Intensity of HGFs in each sector. All years pooled together. Sectors are sorted, such that those with the highest HGF proportions appear at the top of the table.

SECTOR	Proportion HGFs	Total
Construction	0.352	1804
Research and Development	0.333	54
Public Administration	0.310	4508
Other Services	0.282	482
Mining	0.279	1129
Finance	0.271	2465
Consultancy and Services	0.269	3811
Real Estate	0.266	530
Agroindustrial and Farming	0.266	1690
Vehicles	0.256	1649
Fishing	0.253	676
Recycling	0.250	36
Transport	0.242	2003
Publishing	0.242	207
Computation	0.239	536
Hydrocarbons	0.236	1265
Mining Non-Metallic	0.226	434
Metalwork	0.220	2178
Telecom	0.220	537
Health	0.217	713
Renting (Machinery)	0.216	171
Organizations	0.213	465
Plastic	0.212	1054
Commerce	0.208	14883
Tourism	0.207	1985
Paper	0.205	244
Education	0.200	1448

(*Continued*)

Table A1.
Intensity of HGFs in each sector. All years pooled together. Sectors are sorted, such that those with the highest HGF proportions appear at the top of the table.

SECTOR	Proportion HGFs	Total
Recreation	0.198	460
Food	0.193	1105
Post	0.190	84
Pharmaceutical Labs	0.177	265
Chemical	0.171	914
Leather	0.169	142
Forestry	0.169	154
Beverage	0.165	170
Textiles	0.160	1295
Tobacco	0.154	13
Energy and Water	0.144	930
Printing	0.127	284
Lawyers	0.080	213
Total	0.234	52986

ARTÍCULO

DOES FIRM INNOVATION LEAD TO HIGH GROWTH? EVIDENCE FROM ECUADORIAN FIRMS

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Grijalva, D. F., Ayala, V., Ponce, P. A., & Pontón, Y. (2018). Does firm innovation lead to high growth? Evidence from Ecuadorian firms. ***Cuadernos de Economía*****, *37*(75), 697-726.**

We analyze the determinants of: i) employment and sales growth, and ii) the likelihood of becoming a high-growth firm (HGF) among Ecuadorian firms for the

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We thank two anonymous reviewers for detailed suggestions. We also thank participants at the First IZA / World Bank / NJD Jobs and Development Conference 2018 for their helpful comments.

Sugerencia de citación: Grijalva, D. F., Ayala, V., Ponce, P. A., & Pontón, Y. (2018). Does firm innovation lead to high growth? Evidence from Ecuadorian firms. *Cuadernos de Economía, 37*(75), 697-726. doi: 10.15446/cuad.econ.v37n75.68621

Este artículo fue recibido el 01 de diciembre de 2017, ajustado el 28 de mayo de 2018, y su publicación aprobada el 31 de mayo de 2018.

period 2011-2014. We apply a two-stage econometric model that controls for selection bias in the choice to innovate in regards to the two rounds of the Ecuadorian National Innovation Activities Survey. We find that younger firms and firms that spend more on R&D activities per employee have significantly higher levels of employment growth and are significantly more like to become employment HGFs.

Keywords: Firm growth, high-growth firms, job creation, entrepreneurship, innovation.
JEL: D22, L26, M21, O3, O54.

Grijalva, D. F., Ayala, V., Ponce, P. A., & Pontón, Y. (2018). ¿La innovación empresarial conduce al alto crecimiento? Evidencia de empresas ecuatorianas. *Cuadernos de Economía*, 37(75), 697-726.

Analizamos los determinantes de: 1) crecimiento del empleo y de las ventas, y 2) la probabilidad de convertirse en una empresa de alto crecimiento entre las compañías ecuatorianas para el periodo 2011-2014. Aplicamos un modelo econométrico de dos etapas que controla el sesgo de selección en la elección de innovar con respecto a las dos rondas de la Encuesta Nacional de Actividades de Innovación de Ecuador. Encontramos que las empresas más jóvenes y aquellas que invierten más en actividades de investigación y desarrollo por empleado tienen niveles significativamente mayores de crecimiento del empleo y son significativamente más propensas a convertirse en empresas de alto crecimiento de empleo.

Palabras clave: crecimiento empresarial, empresas de alto crecimiento, creación de empleo, espíritu emprendedor, innovación.
JEL: D22, L26, M21, O3, O54.

Grijalva, D. F., Ayala, V., Ponce, P. A., & Pontón, Y. (2018). L'innovation dans l'entreprise conduit-elle à la forte croissance ? L'exemple des entreprises équatoriennes. *Cuadernos de Economía*, 37(75), 697-726.

Nous analysons les facteurs déterminants de : 1) la croissance de l'emploi et des ventes, et 2) la possibilité de se transformer en entreprise à forte croissance pour les compagnies équatoriennes pour la période 2011-2014. Nous utilisons un modèle économétrique en deux étapes qui contrôle le biais de sélection dans la décision d'innover par rapport aux deux séries de l'Enquête Nationale d'Activités d'Innovation de l'Equateur. Nous observons que les entreprises les plus jeunes et celles qui investissent davantage dans des activités de recherche et de développement par employé ont des niveaux significativement plus importants de croissance de l'emploi et sont plus significativement propices à se convertir en entreprises à forte croissance d'emploi.

Mots-clés: Croissance de l'entreprise, entreprises à forte croissance, crétaion d'emploi, esprit d'entreprise, innovation.
JEL: D22, L26, M21, O3, O54.

Grijalva, D. F., Ayala, V., Ponce, P. A., & Pontón, Y. (2018). A inovação nos negócios leva a um alto crescimento? Evidências de empresas equatorianas. *Cuadernos de Economía*, 37(75), 697-726.

Analisamos os determinantes de: 1) crescimento do emprego e das vendas, e 2) a probabilidade de se tornar uma empresa de alto crescimento entre as empresas equatorianas para o período 2011-2014. Aplicamos um modelo econométrico de dois estágios que controla o viés de seleção na escolha de inovar em relação às duas rodadas da Pesquisa Nacional de Atividades de Inovação do Equador. Descobrimos que as empresas mais jovens e aquelas que investem mais em atividades de pesquisa e desenvolvimento por funcionário têm níveis significativamente mais altos de crescimento de emprego e são significativamente mais propensas a se tornarem empresas de alto crescimento de emprego.

Palavras-chave: crescimento empresarial, empresas de alto crescimento, criação de empregos, espírito empreendedor, inovação.
JEL: D22, L26, M21, O3, O54.

INTRODUCTION

In recent years there has been a growing interest in high-growth firms (HGFs), as they contribute to several key objectives of public policy. Most importantly, HGFs seem to generate economic growth (Schreyer, 2000) through the following mechanisms. First, following the work of Birch (1979), a large amount of literature has shown that HGFs are typically responsible for a large fraction of employment creation despite constituting a small share of total employment (Henrekson & Johansson, 2010). For instance, Storey (1994) finds that in the United Kingdom around four percent of firms create approximately half of the new jobs over a decade. In addition, HGFs generate business for other firms (SEAF, 2007), further contributing to employment and economic growth. Second, there is evidence that the jobs created by HGFs tend to be better ones. Olafsen & Cook (2016) find that HGFs' jobs pay higher wages than national averages and that their employees tend to report higher job satisfaction. This makes intuitive sense as HGFs are successful companies, capable of providing better working conditions. Third, HGFs also contribute to product and process innovation, and thus to productivity (Bartelsman, Scarpetta & Schivardi, 2005). Likewise, Olafsen & Cook (2016) argue that there is a set of high-growth firms that focus on innovation as a mechanism to grow. According to these authors, such firms are important because they enhance competition and diversification, and contribute to improved consumer choice.

HGFs thus constitute the cornerstone of the microfoundations of economic growth and, as a consequence, are considered central to economic development policy (Autio & Rannikko, 2016). If the growth of HGFs can be sustained over time, there is a case to be made in favor of policies that promote growth and support these firms over time. However, the scant existing evidence indicates that HGFs' growth is *not* persistent. For example, Daunfeldt & Halvarsson (2015) find that among Swedish firms high growth in a given period is associated with job losses in the previous one and a very low probability of high growth in the next one. Although the conclusions regarding persistence depend on how growth is measured (Hölzl, 2014), it seems that HGFs cannot be identified ex-ante (Hölzl, 2009). Indeed, Falkenhall & Junkka (2009) find that there is a replacement effect according to which HGFs in a given period are replaced by other HGFs in the next period. Only a very small fraction of firms manage to sustain high growth over longer periods of time.

Most of the discussion on HGFs is based on evidence from OECD countries, which are significantly different from less developed ones regarding their economic structure, levels of innovation, distance to the technological frontier, nature of entrepreneurship, etc. It is thus important to expand our understanding of HGFs in non-OECD countries. In the specific case of Ecuador, there is no study available on HGFs. This paper contributes to this gap by analyzing the determinants of Ecuadorian firms' growth and their likelihood of becoming HGFs.

We find that younger firms and those that spend more on R&D per employee have significantly higher levels of employment growth. Likewise, firms that spend

more on R&D per employee are significantly more likely to become employment HGFs. However, the size of the firms does not have an effect on either of these variables. We also find that belonging to a business group has a negative effect on both variables.

Our results on sales growth and sales HGFs are much less precise. Most importantly, R&D expenditure does not have an effect on either sales variable. Smaller firms have higher sales growth, as well as those with a *lower* share of exports on sales and those that invest *less* on fixed capital per employee, although the last result is only marginally significant.

Our results show how our conclusions on HGFs can vary significantly depending on the chosen growth variable, and these differences can have important consequences for policy.

LITERATURE REVIEW

A large amount of literature on HGFs and their determinants emerged following the work of Birch (1979). Despite the large number of theoretical and empirical analyses, there is no common definition of what exactly constitutes a HGF. Therefore, it is hardly surprising that there is no consensus about which factors contribute to their creation. In this section we briefly discuss five dimensions that make the definition of HGFs problematic.[1] Considering these limitations, we next present our preferred definition of HGF. Finally, we discuss the variables included in our econometric models and previous evidence regarding their effects on HGFs, emphasizing the role of expenditure on R&D. In this context, we discuss the decisions made regarding the chosen variables.

Why are high growth firms so difficult to define? The first reason is that there is no obvious indicator to measure a firm's growth. Most authors use either employment and/or sales (Delmar, 2006), but other indicators such as productivity, revenue, value added, profit, market share, market value, and asset growth have also been used.[2] This lack of consistency is problematic because different indicators lead to different sets of HGFs, making it difficult to set policy recommendations.[3] Moreover, as we show in section 5, the factors that influence HGFs vary depending on the chosen indicator.

Second, growth can be measured in relative and absolute terms. The former is biased in favor of small firms, while the latter is biased in favor of large firms (Delmar, 1997). In either case, it is not clear what threshold to use and whether the threshold should be defined in absolute terms (e.g. employment growth of 25% or

[1] See Moreno & Coad (2015) for an expanded discussion on most of these dimensions.

[2] See Daunfeldt, Elert & Johansson, (2010) and Daunfeldt, Elert & Johansson (2014) for a discussion of the implications of using different indicators to measure firms' growth.

[3] Coad (2010), however, shows that the correlation is moderately high when using employment and sales.

more per year as in Haltiwanger, Jarmin & Miranda, 2013) or with respect to the relative performance of the firms (e.g. the 5% of firms with the highest employment growth as in Coad, Daunfeldt, Hölzl, Johansson & Nightingale 2014). As a response to this problem, several authors have used the Birch index, which combines relative and absolute growth.[4] Alternatively, to deal with the bias in favor of small firms when using relative growth, OECD/Eurostat (2008) proposes to use a relative measure of growth, but to only include firms with 10 or more employees among HGFs.

Third, because growth implies a change in quantity over time, either one of these dimensions can be emphasized. As a consequence, some authors have focused on quantity (high-growth firms)[5] while others have focused on time (fast-growth firms or similar definitions).[6] This distinction is key because recent research has shown that HGFs are not in general able to sustain their levels of growth over longer time-frames (Hölzl, 2014), and indeed are characterized by low profits and a weak financial position *before* their high growth periods (Daunfeldt & Halvarsson, 2015). As a consequence, Braennback, Carsrud & Kiviluoto, (2014) argue that growth, and in particular high and fast growth, is not always good for the firm and emphasize instead the role of profitability and sustainability.

Fourth, related to the previous point, it is not clear over what period to measure growth. Indeed, it varies from the shortest, typical analysis of Henrekson & Johansson (2010), who consider HGFs to be firms that grow more than 20% per year for a period of three or four consecutive years, to Fritsch & Weyh (2006), who use a period of 18 years. Of course, part of this variation responds to the issue of sustainability and availability of data. In particular, as more data becomes available, it is possible to look at HGFs' behavior over longer time-frames.

Finally, the nature of a firm's growth is important. Firms can grow organically (internal growth) or by acquisition (mergers or acquisitions) (Delmar, Davidsson & Gartner, 2003). Conceptually, this distinction is clear, and OECD/Eurostat (2008) recommends not considering a firm as HGF when its growth has been due to a merger or an acquisition. In practice, however, research has focused on total growth (the sum of organic growth and acquisition growth) mainly due to limitations in the datasets (Coad, Daunfeldt, Johansson & Wennberg, 2014). In our sample we do not include firms that have experienced a merger or an acquisition over the period of analysis.

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[4] Consider employment growth. Letting L_i represent the number of employees in firm i, the formula for the Birch index is given by: $BI = (L_{i,t+1} - L_{i,t})\dfrac{L_{i,t+1}}{L_{i,t}}$.

[5] See e.g. Segarra & Teruel (2014)

[6] Birch (1981) uses the term "gazelles", Almus (2002) uses "fast-growth firms", Schreyer (2000) uses "rapidly expanding firms", and Coad & Rao (2008) use "'superstar fast-growth firms".

Considering these limitations, in our analysis we follow OECD/Eurostat (2008), who define a HGF as a firm with average annualized growth greater than 20% per year over a three-year period (i.e. 72.8%) and with ten or more employees at the beginning of the observation period.[7]

We measure growth in terms of employment and sales. These variables are the most commonly used in the literature, and thus provide a natural starting point to allow for comparisons with previous studies. Also, as discussed by Coad (2009), there is a key distinction between sales and employment in that while the former is an output, the latter is an input. As a consequence, because of the productivity enhancements brought about by innovation, there is reason to believe that the effect of innovation on firms' growth may differ depending on whether we look at employment or sales.

In spite of the methodological challenges, there is extensive literature that explores the potential factors that contribute to firms' high growth (see Coad, 2009, for a review). Olafsen & Cook (2016) provide a review of these determinants in general and Nichter & Goldmark (2009) present a detailed analysis for the case of developing countries, specifically for micro and small enterprises. The factors that contribute to growth can be grouped into four categories: i) Individual entrepreneur's characteristics (e.g. education, work experience, gender, age, and psychological traits), ii) Firm characteristics (e.g. age, size, firm's sector, formality, foreign ownership, exports, access to finance, etc.),[8] iii) Relational factors (e.g. entrepreneur's social networks, characteristics of the value chain, and interfirm cooperation), and iv) Contextual factors (e.g. business cycle, price volatility, regulatory and institutional environment, and even cultural characteristics).

Although we agree that many of these factors do play an important role in the case of Ecuadorian HGFs, in this paper we focus only on some of them -mainly because of the nature of the dataset-. Most importantly, we are not able to include individual entrepreneurship, relational and contextual characteristics. We focus only on *some* firm characteristics, specifically age, size, investment in fixed capital, participation in a business group, exports, available skills and, most importantly, innovation expenditure. We next consider the empirical evidence regarding each of these factors.

First, consider a firm's age. A robust finding is that a firm's age and high growth are inversely related (Coad, 2009; Henrekson & Johansson, 2010). Among developed countries, Schreyer (2000) finds this result for Italy, Germany, Netherlands, Spain, Sweden, and Quebec, Canada. Similar results are also confirmed in developing countries. For instance, Burki & Terrell (1998) find that a firm's average

[7] OECD/Eurostat (2008) explicitly identifies gazelles as the subset of HGFs that are less than five years old.

[8] Olafsen & Cook (2016) argue that access to finance is part of the contextual factors. However, in the specific case of Ecuador, we believe that there are systematic differences in access to finance depending on a firm's characteristics. In other words, we deem it more appropriate to consider it a feature of the firm and not of the aggregate context.

growth rate decreases with age in the case of Pakistan. Mead & Liedholm (1998) find a similar result among micro and small enterprises (MSEs) in five African countries and the Dominican Republic.

Regarding the effect of a firm's size on HGFs, the evidence is still mixed. Following the seminal paper by Birch (1979) -who showed that in the United States small firms are responsible for a disproportionate share of job creation-, a debate ensued. Birch's result was later confirmed in Portugal (Mata, 1998) and other countries. However, Schreyer (2000) finds that in the countries that he analyzes, small and large firms contribute to employment gains, with the more significant role coming from *larger* firms. Importantly, he measures growth using the Birch index. More recently, Haltiwanger, Jarmin & Miranda, (2013) find that, in the case of the United States, a firm's size ceases to have a significant effect on growth once age is controlled for.

There is less evidence on the effect of fixed capital investment, participation in a business group, and exports. Oliveira & Fortunato (2017) find that investment in physical capital has a positive effect on the growth of Portuguese manufacturing firms. Almeida, Kim & Kim (2015) show that Korean groups were able to sustain the investment of high-growth firms during the Asian crisis through cross-firm equity investments. Hölzl & Friesenbichler (2007) find strong evidence that exports are positively related to high growth in the case of Austrian firms.

Finally, there has been recent interest on the effect of innovation on high growth. Despite the natural prior that high-growth firms should be innovative, there is conflicting evidence on the effect of innovation [see e.g. the revision in Del Monte & Papagni, 2003). At the theoretical level, based on the idea of creative destruction, Schumpeter (1942) and Nelson & Winter (1982) argue that innovation is a key driver of firm growth. As mentioned above, however, how we measure growth matters: while we expect innovation to have a positive effect on sales growth, its effect on employment growth is uncertain because innovation should lead to a more efficient use of inputs (Coad, 2009). More specifically, in the case of employment growth, product and process innovation may have different effects (Coad & Rao, 2011). Thus, while Hölzl & Friesenbichler (2007) find that *product* innovation has a positive effect on employment growth, Coad & Rao (2008) and Hall, Lotti & Mairesse (2008) find that *process* innovation leads to employment decline. These results are confirmed by Goedhuys & Sleuwaegen (2010) in the case of 11 African countries.

One key issue is the measure used to capture innovation. The most common include patent counts and R&D expenditure. Patents are infrequent and also highly skewed in value (Coad, 2009). R&D statistics are smoothed but are an innovative input, which does not necessarily reflect innovative output. We prefer the later because: i) in the case of Ecuador, patents are very scarce, and ii) we would like to capture the effects of innovative *effort*, which is a firm's choice not affected by uncertainty.

More generally, innovation is a highly uncertain process that can be seen as a high-risk high-gain strategy (Hölzl, 2009). Indeed, Coad & Rao (2010b) find that innovation is positively related to the *variance* of US manufacturing firms' growth, while Oliveira & Fortunato (2017) find that R&D expenditure has no effect on Portuguese manufacturing firms' growth and Demirel & Mazzucato (2012) find that it can actually have a *negative* effect on the growth of large US pharmaceutical firms. Oliveira & Fortunato (2017) argue that a possible reason for their result is that Portuguese firms have low R&D expenditure, which is consistent with the evidence that there are important differences between countries. For instance, Hölzl (2009) finds that HGFs in countries far from the technological frontier require less R&D investment. Another possible reason for their result is that innovative efforts may appear only after a lag. Some papers have emphasized the role of persistence in innovation as a determinant of a positive effect on firms' growth (Deschryvere, 2014; Triguero, Córcoles & Cuerva, 2014). Indeed, in their analysis of Spanish manufacturing firms, Triguero et al. (2014) find that the positive effect of innovation on employment growth is *larger* after one or two years.

Another important dimension regarding the effect of innovation on firm growth is its heterogeneity across firms' distribution, both between and within industries. Henrekson & Johansson (2010) survey the literature on HGFs and find that they are not over-represented in high-tech sectors. Indeed, in the case of Swedish firms, Daunfeldt, Elert & Johansson, (2016) find that HGFs are less frequent in sectors with high levels of R&D investment and Del Monte & Papagni (2003) find that the effect of R&D investment on Italian firms' growth is greater in traditional sectors than in sectors with high research intensity. Likewise, Coad & Rao (2008) find that innovation has no effect on the mean of the growth distribution of US firms, but its effect is significant at the upper quantiles.

Finally, more recent research argues that firm growth is a multidimensional process in which various forms of growth (sales, employment, profit and labor productivity/R&D investment) co-evolve (Coad, 2010; Coad & Rao, 2010a). This analysis is important because it highlights that causality may run in the opposite direction. In particular, using a VAR model, Coad & Rao (2010a) find that employment and sales growth *lead* to growth in R&D expenditure, but not the other way around. Consistent with this result, as explained below, in order to mitigate the issue of reverse causality we conduct an econometric model with lagged regressors.

HIGH-GROWTH FIRMS IN ECUADOR

In this section we provide a description of the main characteristics of Ecuadorian HGFs. Before that, we discuss briefly the datasets used in the analysis.

Datasets

We use the two rounds of the Ecuadorian National Innovation Activities Survey of 2012 and 2015, implemented by the National Institute of Statistics and Censuses

(INEC).[9] These surveys are based on the methodology proposed by OECD/ Eurostat (2005) and aim to compile representative data on the innovative activities undertaken by firms in Ecuador. In particular, they provide information about basic firms' characteristics including start date, size, industry, international orientation, and participation in business groups. Likewise, the surveys provide information on different types of innovation: product, process, organizational, and marketing. Finally, they include information on sources of financing, R&D expenditures, patents and licenses, constraints of innovation, etc.

The 2012 Innovation Survey includes data for the years 2009-2011 for a representative stratified sample of 2,815 firms with more than 10 employees from the manufacturing, services and commerce sectors. The 2015 Innovation Survey includes data for the years 2012-2014, and has a sample of 6,275 firms. The surveys display significant heterogeneity in terms of firm size, age, industry, international orientation, and participation in business groups.

The two rounds include a panel of 1,065 firms, which is the initial sample used in our analysis. We restrict this sample in two ways. First, we exclude firms that have experienced a merger or an acquisition at any point during the whole period (2009-2014). Second, to control for outliers, we exclude firms that had a growth of more than 250% in any given year. Our final sample comprises 993 firms. From this total, 91 firms (9.16%) are employment-based HGFs and 180 firms (18.13%) are sales-based HGFs.

Descriptive Statistics of Ecuadorian HGFs

To reduce the problem of reverse causality and capture the lagged effect of R&D expenditure, we focus on firm growth during the period 2011-2014, and look at its determinants during the period 2009-2011. Table 1 provides an overview of employment, sales, and productivity growth for the period 2011-2014 among 993 Ecuadorian firms, classified by deciles based on employment growth (top panel) and sales growth (bottom panel).[10] Several interesting results follow immediately.

First, during this period and for the full sample, employment grew by 20.37%, sales by 75.88%, and productivity by 104.43%. These are remarkable changes and are consistent with a period of strong economic growth characterized by the peak of the commodities boom in Ecuador (Gachet, Grijalva, Ponce & Rodríguez, 2017; forthcoming). Second, there is large variation across deciles, consistent with a strong process of creative destruction. Regarding employment, among firms in the lowest decile, the number of employees falls by 60.04% but it increases by 184.33% in the highest one. Regarding sales, in the lowest decile they fall by an average of 78.48%, while they increase by an impressive 687.62% in decile ten. Third, the table also shows that labor productivity growth is very high in the *lower*

[9] This survey is known as *Encuesta Nacional de Actividades de Innovación ACTI.*

[10] Our measure of productivity is the ratio of sales to the number of employees and thus corresponds to labor productivity only.

deciles of employment growth, but it tends to fall as we move towards the upper deciles. Except for deciles two and four, the opposite occurs with sales deciles, where in general productivity growth is low or negative in the lower deciles, increasing thereafter.

Table 1.
Firms' Employment, Sales and Productivity by Deciles, 2011-2014

Employment			
Deciles by employment	**Average growth rate of employment**	**Average growth rate of sales**	**Average growth rate of productivity**
1	-60.04	39.40	605.99
2	-23.50	56.47	101.47
3	-10.55	8.97	21.24
4	-1.85	83.09	86.46
5	4.17	41.46	35.83
6	10.91	89.06	71.20
7	20.03	46.81	22.60
8	31.98	91.20	46.21
9	52.01	83.36	21.76
10	184.33	216.39	15.80
Sales			
Deciles by sales	**Average growth rate of employment**	**Average growth rate of sales**	**Average growth rate of productivity**
1	2.76	-78.48	-62.52
2	-10.42	-35.78	325.86
3	1.12	-16.30	-6.99
4	-1.87	-4.02	89.07
5	19.23	6.62	8.08
6	14.41	16.74	10.44
7	19.72	28.91	15.78
8	21.61	51.01	37.62
9	47.05	105.37	59.53
10	90.46	687.62	570.15
Total sample	**20.37**	**75.88**	**104.43**

Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 2.
Characteristics of High Growth Firms (HGFs) by Employment and Sales. 2011-2014

	HGF by employment		non-HGF by employment		HGF by sales		non-HGF by sales	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**	**Mean**	**Median**
Number of firms (2011)	91		902		180		813	
Number of employees (2011)	146.49	45.00	277.76	72.00	148.89	47.50	291.60	79.00
Age of firms (2011)	21.64	20.00	28.88	24.00	24.77	20.00	28.98	24.00
Growth rate of employment (2011-2014, %)	194.33	116.79	2.82	3.92	71.29	29.29	9.09	4.01
Growth rate of sales (2011-2014, %)	225.49	84.76	60.79	8.61	429.25	194.80	-2.35	2.58
Growth rate of productivity (2011-2014, %)	14.85	-20.78	113.46	6.56	342.87	134.82	51.64	-2.89
Firms with R+D activities (2009-2011, %)	27.47	-	31.04	-	28.89	-	31.12	-
R+D expend. per employee (2009-2011, US$ of 2016)	446.75	0.05	378.26	0.04	269.42	0.05	410.02	0.04
Fixed capital expenditure per employee (2009-2011, US$ of 2016)	8,675.38	1,732.46	6,891.82	908.68	4,432.74	799.01	7,635.90	974.59
Firms belonging to a business group (2011, %)	21.98	-	23.06	-	17.78	-	24.11	-
Foreign capital in firms (2011, %)	13.80	-	11.70	-	9.60	-	12.40	-
Firms that are public (2011, %)	1.10	-	2.99	-	2.22	-	2.95	-

Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 2 looks specifically at HGFs vs. non-HGFs by employment and sales. The first feature of Ecuadorian HGFs is that there are many more HGFs by sales than by employment growth (180 vs. 91). This is consistent with previous studies (see e.g. Segarra & Teruel, 2014) and is what we would expect given rational behavior by firms: Faced with a positive shift in demand, which is not necessarily permanent, firms should modify the variable labor factor of production (i.e. hours per worker). In this case, we would observe an increase in sales without an increase in employment. Only when firms expect the shift in demand to be permanent, should they modify the fixed labor factor of production (i.e. number of workers). Second, Ecuadorian HGFs tend to be significantly smaller. On average, they have around half the number of employees compared to non-HGFs. Third, HGFs are younger than their counterparts: seven years in the case of employment and four years in the case of sales. Fourth, independently of whether we measure growth in terms of employment or sales, HGFs are very different from their non-HGFs counterparts. In the case of employment, the median rate of employment growth among HGFs is almost 30 times that of non-HGFs. In the case of sales, the median rate of sales growth among HGFs is almost 76 times that of non-HGFs.

As we mentioned before, a key distinction between employment HGFs and sales HGFs is their productivity growth. While the average growth of labor productivity among sales-HGFs is almost seven times the average growth among their counterparts, average productivity growth among employment-HGFs is around one-eighth of their counterparts average growth rate. In fact, the median growth rate of productivity among HGFs by employment is -20.78%.

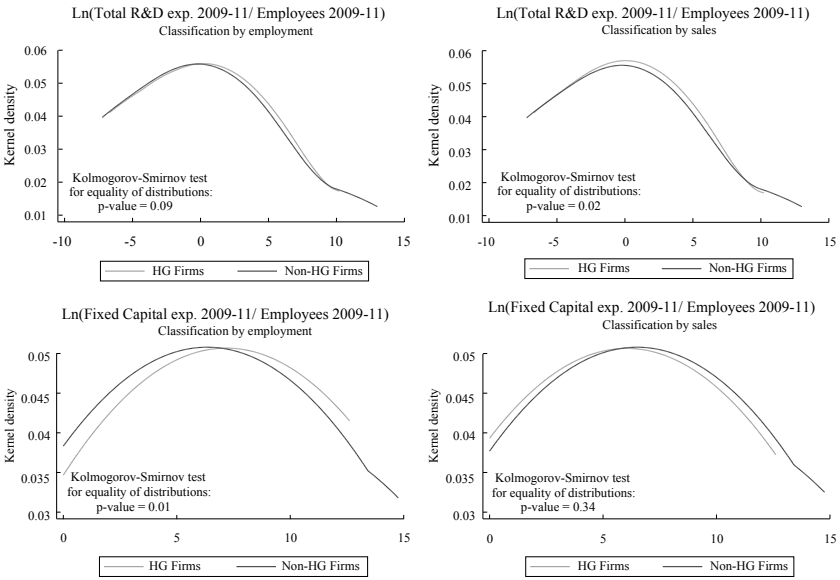
Regarding the relationship between R&D expenditure and HGFs in particular, Table 2 shows two interesting results. On the one hand, a smaller share of HGFs choose to perform innovation activities compared to non-HGFs, both for employment and sales-HGFs. On the other hand, there is a clear difference in the amount spent among HGFs, depending on whether we look at employment or sales. Employment-HGFs spend on average 18% more on R&D per employee than their counterparts, while sales-HGFs spend over 34% *less* on R&D per employee than their counterparts.[11]

Finally, regarding fixed capital expenditure per employee, on average employment-HGFs invest almost 26% more than their counterparts. Sales-HGFs, on the contrary, invest less than 60% of their counterparts' average.

To further look at the relationship between firms' R&D and capital expenditure per employee, and their classification as HGFs, Figure 1 presents a comparison of these variables' distribution among HGFs and non-HGFs based on employment and sales for the period 2009-2011. The figure also reports Kolmogorov-Smirnov tests for the equality of the distributions. As can be seen, there exist non-HGFs that have particularly high levels of R&D and capital expenditure, which affect the means reported in Table 2. Still, the Kolmogorov-Smirnov test rejects equality of distributions in three of the four panels (p-value < 0.1) showing that the distribution of R&D expenditure in all cases and capital expenditure in the case of employment-HGFs is different compared to their counterparts.

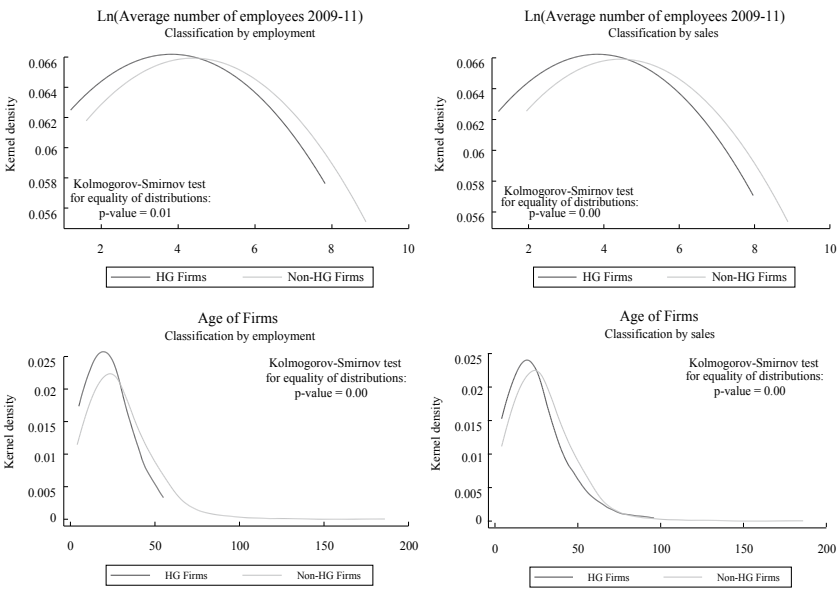
[11] In this case, medians are not informative due to the large number of firms with zero investment in R&D.

Figure 1.
Kernel Densities of R&D and Fixed Capital Expenditure (HGFs vs. non-HGFs)



Source: Authors' elaboration based on INEC (2012) and INEC (2015).

Figure 2.
Kernel Densities of Size and Age (HGFs vs. non-HGFs)



Source: Authors' elaboration based on INEC (2012) and INEC (2015).

Figure 2 provides similar information to Figure 1 for firm's size and age. It shows that Ecuadorian HGFs (based both on employment and sales) are both smaller and younger than non-HGFs. Interestingly, as shown below, the age effect dominates when analyzing the case of employment HGFs (Table 6), while the size effect dominates in the case of sales HGFs (Table 8).

In line with the previous literature, Ecuadorian firms thus show the importance of the indicator used to classify HGFs. Using employment or sales gives rise to different sets of firms with different characteristics. Most importantly, HGFs that create jobs are those that invested more in R&D, but this is not the case with sales-HGFs.

ECONOMETRIC ANALYSIS

Our main purpose is to estimate the effects of innovation expenditure on firms' employment and sales growth, and on the likelihood of them becoming HGFs. There are two econometric issues that need to be addressed. First, our model can be affected by selection bias because a firm's decision to invest in innovation is not random. As a consequence, inference based on an OLS analysis would be biased. Second, simultaneity should be taken into account because reverse causation cannot be ruled out. In particular, while our analytical perspective considers the effect of innovation on firms' growth, it is possible that firms that experience higher levels of growth choose to invest more on innovation.

To correct for selection bias, we divide our analysis into two main stages. In the first one we analyze the determinants of innovation expenditure, correcting them based on selection bias. We use the Heckman two-step method (Heckman, 1979). The first step considers the determinants of the firms' decision to innovate. The inverse Mills ratio obtained from this regression is added to the second step, which considers the determinants of innovation expenditure. We decided to use the two step method instead of a maximum likelihood estimation because it is more robust and does not require the errors of the selection and output models to be bivariate normal (Wooldridge, 2002).

The second stage varies depending on our response variable. When we analyze firms' growth, we run an OLS model with continuous growth as the dependent variable, again including the inverse Mills ratio. When we analyze the likelihood of becoming a HGF, we use a probit model.

To (partially) correct for simultaneity we specify our dependent variables in the second stage forwarded with a period in regard to the regressors. In particular, all growth variables are defined for the period 2011-2014 (i.e. three growth years), while all regressors are defined for the period 2009-2011. Hence, although our database is a panel of firms, our analysis is actually cross-sectional.

The details of our approach are explained next. First, following Heckman (1979) we specify the selection equation by modeling the propensity of a firm to be part of the sample by using a probit regression of y_1, which indicates whether firms decide to innovate or not:

$$Pr(y_1 = 1 \mid \mathrm{x}_1) = \Phi(\mathrm{x}'_1\beta_1) = \int_{-\infty}^{\mathrm{x}'_1\beta_1} \varphi(z)dz, \tag{1}$$

where $\Phi(\cdot)$ is the cumulative distribution function (CDF) of the standard normal distribution, and x_1 is a vector of explanatory variables, including the logarithm of the firm's average number of employees between 2009 and 2011 to control for size, firm's age in 2011, the logarithm of the firm's average capital expenditure per employee from 2009 to 2011,[12] the firm's average exports as a percentage of sales from 2009 to 2011, the firm's foreign capital percentage in 2011, and the percentage of employees with a higher education degree in 2011. The choice of variables in the selection equation is based on factors that could directly affect whether a firm decides to innovate or not. From this regression, we obtain the inverse Mills ratio defined as the ratio of the probability density function (pdf) to the cumulative distribution function (cdf) of the standard normal distribution:

$$\lambda(\mathrm{x}'_1\hat{\beta}_1) = \frac{\varphi(\mathrm{x}'_1\hat{\beta}_1)}{\Phi(\mathrm{x}'_1\hat{\beta}_1)} \tag{2}$$

In the second step, we estimate the firms' R&D expenditure per employee y_2[13] using an OLS regression of the form:

$$y_2 = \mathbf{x}'_2\beta_2 + \sigma_2\lambda(\mathbf{x}'_1\hat{\beta}_1) + v_i, \tag{3}$$

where $\lambda(\cdot)$ is the inverse Mills ratio obtained in the first step. The vector of covariates x_2 includes the logarithm of the firm's average number of employees between 2009 and 2011, the firm's age in 2011, an indicator variable for whether the firm is part of a business group, an indicator variable for whether the firm is public, the firm's percentage of foreign capital, and the percentage of employees with a higher education degree in 2011.[14]

For the second stage, in the case of continuous growth we use an OLS model for growth y_3 in the period 2011-2014 as follows:

$$y_3 = \mathbf{x}'_3\beta_3 + \sigma_3\lambda(\mathbf{x}'_1\hat{\beta}_1) + u_i, \tag{4}$$

where again $\lambda(\cdot)$ is the inverse Mills ratio from the first stage. The vector of explanatory variables x_3 includes the logarithm of the firm's average number of employees from 2009 to 2011, its age in 2011, the logarithm of average capital expenditure per employee from 2009 to 2011, the logarithm of R&D expenditure per employee from 2009 to 2011, a dummy variable to show if the firm is part of a business group, the share of exports on sales, and the percentage of employees with a higher education degree.

[12]Capital expenditure is measured in real terms using US$ of 2016.

[13]R&D expenditure is measured in real terms using US$ of 2016.

[14]The estimation is conducted in Stata using the command heckman with the option twostep. This option estimates the standard errors as in Heckman (1979).

In the case of HGFs, we use a regular probit model of the form:

$$Pr(y_3 = 1 \mid \mathbf{x}_3) = \Phi(\mathbf{x}_3 \beta_3 + \lambda(\mathbf{x}_1' \hat{\beta}_1)) \tag{5}$$

where y_3 takes a value of one when the firm is a high growth firm for each case (employment or sales) in the period 2011-2014.

Because of the sequential nature of the estimation in the second stage and the inclusion of the inverse Mills ratio ($\lambda(\cdot)$), we estimate the standard errors using the bootstrap method.

RESULTS

We first present results of the two-step Heckman selection model, which is the first stage of all models. Then, we present results for employment growth and HGFs, as well as for sales growth and HGFs. Table 3 summarizes the labels and descriptions of the variables used.

Table 3.
Labels and variable descriptions

Label	Variable description
laemp	Log of average employment
age	Firm's age
lkpe	Log of k expenditure per employee
lrdexp	Log of R&D expenditure per employee
bugr	Business group
asalesexp	Average exports as a percentage of sales
skills	Percentage of employees with a higher education degree
pfk	Percentage of foreign capital
pubcomp	Public company
mills	Inverse Mills ratio

Source: Authors' elaboration based on INEC (2012) and INEC (2015).

Table 4 presents the results from the two-step Heckman model. The first step (selection to innovate) is shown in the upper panel. We conclude that larger firms are more likely to engage in innovation. Additionally, a higher capital expenditure per employee increases the propensity to participate in R&D activities, whereas a higher percentage of foreign capital reduces it. Our findings are congruent with the existing literature, as well as the CDM (Crépon, Duguet and Mairesse) model performed for Ecuador by Llivichuzhca & Tenesaca (2016). In our case, firm's age, average exports as a percentage of sales, and percentage of employees with a higher education degree do not appear to be relevant for the selection model.

Table 4.
Two-step Heckman Model for log of R&D Expenditure per Employee

Probit selection equation	
$laemp_{09\text{-}11}$	0.140***
	(0.036)
age_1	0.003
	(0.003)
$lkpe_{09\text{-}11}$	0.114***
	(0.013)
$asalesexp_{09\text{-}11}$	0.245
	(0.212)
pfk_1	-0.004**
	(0.002)
$skills_1$	0.003
	(0.194)
Constant	-2.059***
	(0.175)
Outcome equation	
$laemp_{09\text{-}11}$	-0.504***
	(0.113)
age_1	-0.004
	(0.007)
$bugr_1$	0.671**
	(0.271)
$pubcomp_1$	-0.497
	(0.582)
pfk_1	0.001
	(0.004)
$skills_1$	0.011**
	(0.533)
Constant	9.796***
	(0.954)

(*Continued*)

Table 4.
Two-step Heckman Model for log of R&D Expenditure per Employee

Error terms	
mills	-1.443***
	(0.510)
Sigma	2.277
Rho	-0.634
Observations	993 (688 censored)
R^2	0.117
Adjusted R^2	0.096

Note: *p<0.1; **p<0.05; ***p<0.01
Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 5.
OLS Model for Employment Growth

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
$laemp_{09\text{-}11}$	–7.410***	1.348	–0.582
	(2.463)	(2.707)	(5.202)
age_1	–0.210*	–0.333*	–0.371**
	(0.118)	(0.173)	(0.182)
$lkpe_{09\text{-}11}$	0.622	1.954	0.194
	(0.833)	(1.329)	(3.295)
$lrdexp_{09\text{-}11}$	0.313	4.882***	4.854***
	(0.513)	(1.858)	(1.866)
$bugr_1$	10.132	–21.264***	–20.190***
	(9.538)	(8.006)	(8.043)
$salesexp_{09\text{-}11}$	–4.888	1.943	–1.069
	(13.683)	(30.694)	(29.434)
$skills_1$	0.245**	0.200	0.169
	(10.058)	(13.219)	(0.146)
mills			–21.319
			(39.227)
constant	46.349***	–24.104	23.431
	(13.246)	(18.142)	(91.275)

(*Continued*)

Table 5.
OLS Model for Employment Growth

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
Observations	993	305	305
R^2	0.027	0.066	0.067
Adjusted R^2	0.020	0.044	0.042
Residual Std. Error	82.992 (df = 985)	63.666 (df = 297)	63.753 (df = 296)
F Statistic	3.913*** (df = 7; 985)	3.011*** (df = 7; 297)	2.881*** (df = 8; 296)

Notes: *p<0.1; **p<0.05; ***p<0.01

Models (1) and (2) use robust standard errors.

Model (3) uses bootstrapped standard errors based on 1000 repetitions.

Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 6.
Probit Model for Employment HGFs

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
$laemp_{09\text{-}11}$	–0.120**	0.082	0.220
	(0.051)	(0.094)	(0.209)
age_1	–0.014***	–0.018**	–0.016
	(0.005)	(0.008)	(0.011)
$lkpe_{09\text{-}11}$	0.035**	–0.002	0.131
	(0.016)	(0.043)	(0.169)
$lrdexp_{09\text{-}11}$	0.001	0.159**	0.160**
	(0.013)	(0.068)	(0.075)
$bugr_1$	0.116	–0.837**	–0.956***
	(0.152)	(0.351)	(0.344)
$salesexp_{09\text{-}11}$	–0.407	–0.106	0.121
	(0.355)	(0.497)	(8.349)
$skills_1$	0.002	–0.000	0.003
	(0.243)	(0.497)	(0.006)
mills			1.554
			(1.943)

(*Continued*)

Table 6.
Probit Model for Employment HGFs

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
constant	–0.786***	–2.151***	–5.653
	(0.217)	(0.677)	(4.450)
Observations	993	305	305
Log Likelihood	–287.718	–76.179	–75.736
Akaike Inf. Crit.	591.436	168.359	169.472

Notes: *p<0.1; **p<0.05; ***p<0.01

Model (3) uses bootstrapped standard errors based on 1000 repetitions.

One or more parameters could not be estimated in 136 bootstrap replications.

Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 7.
OLS Model for Sales Growth

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
$laemp_{09\text{-}11}$	–25.058***	–9.774	–23.054***
	(7.822)	(7.234)	(11.095)
age_1	0.232	–0.704	–0.964
	(0.494)	(0.598)	(0.615)
$lkpe_{09\text{-}11}$	–4.777*	0.050	–12.062*
	(2.750)	(4.910)	(6.963)
$lrdexp_{09\text{-}11}$	–0.533	–11.563	–11.760
	(1.365)	(11.836)	(10.584)
$bugr_1$	–8.722	–24.256	–16.870
	(16.678)	(16.851)	(14.906)
$salesexp_{09\text{-}11}$	–38.903**	–48.265**	–68.988**
	(18.325)	(21.584)	(27.286)
$skills_1$	0.278	0.168	–0.049
	(40.712)	(50.376)	(0.451)
mills			–146.688
			(89.952)
constant	206.368***	200.533***	527.596**
	(41.064)	(77.345)	(206.229)

(*Continued*)

Table 7.
OLS Model for Sales Growth

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
Observations	993	305	305
R^2	0.029	0.045	0.048
Adjusted R^2	0.022	0.022	0.022
Residual Std. Error	282.186 (df = 985)	181.117 (df = 297)	181.087 (df = 296)
F Statistic	4.229*** (df = 7; 985)	1.982* (df = 7; 297)	2.313** (df = 8, 296)

Notes: *p<0.1; **p<0.05; ***p<0.01

Models (1) and (2) use robust standard errors.

Model (3) uses bootstrapped standard errors based on 1000 repetitions.

Source: Authors' estimations based on INEC (2012) and INEC (2015).

Table 8.
Probit Model for Sales HGFs

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
$laemp_{09\text{-}11}$	–0.157***	–0.121	–0.328
	(0.041)	(0.075)	(0.213)
age_1	–0.004	–0.007	–0.011
	(0.003)	(0.006)	(0.009)
$lkpe_{09\text{-}11}$	–0.008	0.013	–0.175
	(0.012)	(0.034)	(0.175)
$lrdexp_{09\text{-}11}$	0.007	–0.011	–0.014
	(0.011)	(0.046)	(0.054)
$bugr_1$	–0.004	–0.308	–0.226
	(0.127)	(0.223)	(0.244)
$salesexp_{09\text{-}11}$	–0.045	–0.331	–0.649
	(0.254)	(0.427)	(35.694)
$skills_1$	0.012	0.000	–0.004
	(0.203)	(0.387)	(0.006)
mills			–2.225
			(2.038)

(*Continued*)

Table 8.
Probit Model for Sales HGFs

	Full sample (1)	**Uncensored (2)**	**Uncensored corrected (3)**
Constant	–0.136	–0.130	4.892
	(0.173)	(0.502)	(4.708)
Observations	993	305	305
Log Likelihood	–454.584	–132.104	–130.899
Akaike Inf. Crit.	925.168	280.207	279.798

Notes: *p<0.1; **p<0.05; ***p<0.01

Model (3) uses bootstrapped standard errors based on 1000 repetitions.

One or more parameters could not be estimated in 4 bootstrap replications.

Source: Authors' estimations based on INEC (2012) and INEC (2015).

In the second step (expenditure on R&D) we observe the opposite effect of firm size. Together, these results imply that larger firms are more likely to invest in innovation, but larger firms also invest less per employee. In particular, a one per cent increase of average employment is associated with a fall in R&D expenditure per employee of 0.50%. In addition, being part of a business group rises innovation expenditure by 67%. Finally, a one point growth in the percentage of employees with a higher education degree is associated with a 1% rise in the R&D expenditure per employee. Importantly, firms' age does not have a significant effect in either step. The inverse Mills ratio is significant at a 1% confidence level, which indicates that the sample selection correction is necessary.

In the second stage we analyze the determinants of continuous growth and HGFs for both employment and sales. In each case we run three different models that allow us to distinguish the effect of correcting for selection. Column (1) analyzes the full sample, which includes firms that choose to innovate and those that do not. Column (2) provides results on the uncensored sample, without correcting for selection. Finally, column (3) shows the results correcting for selection. Consistent with the literature and the results in Table 4, our preferred model is column (3), and we conduct our analyzes based on these results. As will be seen, it is important to restrict the sample to those firms that choose to innovate. But, as shown by an insignificant Mills ratio, controlling for selection in the second stage is not very important.

The results for employment growth and employment-HGFs are shown in tables 5 and 6. Consider first employment growth in Table 5. The first result is that younger firms are associated with higher employment growth. An additional year of existence is associated with a reduction of 0.37 percentage points in employment growth. We find no evidence, however, that firm's size is related to employment growth. Regarding our main variable of interest, we find that a one per cent increase in R&D expenditure per employee implies an increase of 4.9 percentage points in employment

growth. This shows that innovation plays a very large role on firm's growth. We also find that being part of a business group reduces employment growth by around 20 percentage points.

Examining the determinants for the probability of becoming an employment-HGF (Table 6), we observe that a firm's age is no longer significant. We also find that R&D expenditure per employee has a significant and positive impact on the propensity of becoming a HGF. But, being part of a business group reduces this likelihood. Firm size and capital expenditure per employee do not appear to be significant determinants of HGFs. Thus, except for age, the determinants of employment growth are similar to the determinants of a firm becoming a HGF based on employment. Most importantly, and consistent with Haltiwanger et al. (2013) we find that once we control for age, a firm's size is not relevant for either employment growth or for becoming a HGF based on employment.

Tables 7 and 8 present the OLS and probit models for sales growth and sales-HGF, respectively. The results for growth show that larger firms tend to grow more slowly than smaller ones: a 1% increase on average employment is associated with a 23 percentage point decrease in sales growth. Likewise, capital investment seems to negatively affect sales growth, and average exports as a percentage of sales reduces sales growth considerably.

From the probit model for high growth we see that a firm's size, age, capital expenditure per employee, being part of a business group, and average exports as a percentage of sales do not affect the likelihood of a firm becoming a sales-HGF. In general, from the models based on sales, we conclude that, in the case of Ecuador, the standard variables found in the literature do a poor job in explaining a firm's growth in terms of sales or the likelihood of becoming a HGF based on sales. In particular, it is notable that R&D expenditure is not relevant. A possible explanation is that sales growth during the peak of the commodities boom may be explained by other factors, particularly the increased income from oil.

CONCLUSION

In this paper we present the first analysis of HGFs in Ecuador based on the two rounds (2012 and 2015) of the National Survey of Innovation Activities. To reduce the problem of simultaneity, we analyze firms' growth over the period 2011-2014, based on lagged variables corresponding to the period 2009-2011. Likewise, to correct the problem of selection bias on innovation activities, we estimate a two-stage model that, in the first stage, includes a two-step Heckman selection model.

Our main results regarding sales growth are as follows. First, the common regressors used in the literature do not do a very good job in explaining the likelihood of becoming a sales-HGF in Ecuador. Second, regarding our main variable of interest, innovation does not have an effect on either the growth of sales or the likelihood of becoming a sales-HGF. However, size, capital investment, and the share

of exports on sales do have a *negative* effect on sales growth. As we mentioned above, it is possible that because our period of analysis focuses on firms' growth during the peak of the commodities boom (2011-2014), other mechanisms played a more central role in explaining sales growth. For instance, because of the additional income from oil, it is possible that firms were able to increase their sales independently of their innovative efforts. It is unlikely that the same dynamic would apply under a different scenario. Still, these are empirical questions that need to be addressed in future research.

Our main results regarding employment growth are the following. First, innovation plays a key role on a firm's employment growth in terms of continuous growth and the likelihood of becoming a HGF. Second, younger firms tend to create more jobs, although they do not display a larger likelihood of becoming employment-HGFs. These results are important because they highlight areas where policy can contribute to the generation of employment through its effect on firm growth. Providing incentives for innovation and for young firms seems to be the right approach if the goal is to encourage job creation. Importantly, because size does not seem to affect employment growth, an emphasis on small firms seems unwarranted.

In the case of Ecuador, there is ample space to implement these policies. For instance, according to INEC and SENESCYT (2016), between 2009 and 2014, total expenditure on R&D reached between 0.39% and 0.44% of GDP. While this represents a significant improvement from early years (in 2001 it was 0.06% of GDP and before 2006 it was 0.09% at most) it still lags behind the regional average of around 0.70% (RICYT, 2017). This is particularly worrisome considering that the estimated social return on investment in R&D in Ecuador is 47% (Guaipatin & Schwartz, 2014) and also that Latin America as a whole lags behind other regions (Devlin & Moguillansky, 2011). Furthermore, these levels of innovation occurred in a period of abundance of resources marked by the commodities boom. It is likely that the current economic slowdown in Ecuador might restrict innovation.

In any case, it is important to remember that the promotion of innovation requires a broad set of complementary policies. Previous research shows that effective innovation requires much more than financial resources (Guaipatin & Schwartz, 2014). It emphasizes the need for better public institutions, timely identification of priorities, greater public-private interaction, increased human talent, and support for entrepreneurship (Guaipatin & Schwartz, 2014).

There is one important caveat that needs to be considered. As mentioned in the literature review, there is evidence that growth tends to be unsustainable and firms that manage to grow quickly in a given period do not do so before or after. In addition to the relatively short period of analysis, the characteristics of the specific period may also affect our results. We are not able to deal with these limitations due to the availability of data. In order to address them our results need to be complemented with other analyses that look specifically at the sustainability of high growth among Ecuadorian firms over longer periods covering different contexts.

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ARTÍCULO

DO PROFITABLE START-UP FIRMS GROW FASTER? EVIDENCE FROM COLOMBIA*

Yuji Honjo

Honjo, Y. (2018). Do profitable start-up firms grow faster? Evidence from Colombia. *Cuadernos de Economía*, *37*(75), 727-754.

This study explores the impact of profitability on the growth of start-up firms. Using data on start-up firms in Colombia, we examine the relationship between firm growth and profitability. We provide evidence that start-up firms with higher profitability increase their total assets. However, we find little evidence that profitability positively affects sales growth for start-up firms. In contrast, the results provide support for the notion that profitability is derived from sales growth. Furthermore, we find that firm growth depends heavily on firm age during the start-up stage.

Keywords: Growth; Profitability, Start-up.
JEL: L21; L26; M13.

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* This study has been financially supported by JSPS KAKENHI (Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research) Grant Number JP16H02027. This study has also been financially supported by Chuo University Special Grant for Special Research. I am grateful to two anonymous reviewers for their valuable comments.

Suggested citation: Honjo, Y. (2018). Do profitable start-up firms grow faster? Evidence from Colombia. *Cuadernos de Economía, 37*(75), 727-754. doi: 10.15446/cuad.econ.v37n75.69123

Este artículo fue recibido el 30 de noviembre de 2017, ajustado el 05 de marzo de 2018, y su publicación aprobada el 12 de marzo de 2018.

Honjo, Y. (2018). ¿Las empresas emergentes rentables crecen más rápido? Evidencia de Colombia. *Cuadernos de Economía*, *37*(75), 727-754.

Este estudio explora el impacto de la rentabilidad en el crecimiento de las empresas emergentes o *startups*. Empleando datos sobre empresas emergentes en Colombia, examinamos la relación entre el crecimiento empresarial y la rentabilidad. Proporcionamos evidencia de que las empresas emergentes con mayor rentabilidad incrementan sus activos totales. Sin embargo, encontramos poca evidencia de que la rentabilidad afecte positivamente el crecimiento de las ventas para las compañías emergentes. Por el contrario, los resultados apoyan la noción de que la rentabilidad se deriva del crecimiento de las ventas. Adicionalmente, encontramos que el crecimiento empresarial depende en gran medida de la edad de la empresa durante la etapa de emergencia de la misma.

Palabras clave: crecimiento, rentabilidad, empresa emergente (*startup*).
JEL: L21; L26; M13.

Honjo, Y. (2018). Les entreprises émergentes rentables croissent-elles plus vite ? Exemple de la Colombie. *Cuadernos de Economía*, *37*(75), 727-754.

Cette étude analyse l'impact de la rentabilité sur la croissance des entreprises émergentes ou *startups*. En utilisant des données sur les entreprises émergentes en Colombie, nous examinons la relation entre la croissance de l'entreprise et la rentabilité. Nous montrons que les entreprises émergentes les plus rentables augmentent le total de leurs actifs. Cependant, nous trouvons peu d'évidences de ce que la rentabilité augmente notablement les ventes des compagnies émergentes. Au contraire, les résultats montrent que la rentabilité provient de la croissance des ventes. En outre, nous observons que la croissance de l'entreprise dépend en grande mesure de l'âge de l'entreprise durant l'étape de son émergence.

Mots-clés: croissance, rentabilité, entreprise émergente (*startup*).
JEL: L21; L26; M13.

Honjo, Y. (2018). As empresas emergentes lucrativas crescem mais rápido? Evidências da Colômbia. *Cuadernos de Economía*, *37*(75), 727-754.

Este estudo explora o impacto da lucratividade no crescimento de empresas emergentes ou *startups*. Usando dados de empresas emergentes na Colômbia, examinamos a relação entre o crescimento dos negócios e a lucratividade. Fornecemos evidências de que empresas emergentes com maior lucratividade aumentam seus ativos totais. Porém, encontramos poucas evidências de que a lucratividade afeta positivamente o crescimento das vendas de empresas emergentes. Pelo contrário, os resultados apoiam a noção de que a lucratividade é derivada do crescimento das vendas. Além disso, descobrimos que o crescimento dos negócios depende em grande parte da idade da empresa durante a sua fase de emergência.

Palavras-chave: crescimento, rentabilidade, empresa emergente (*startup*).
JEL: L21; L26; M13.

INTRODUCTION

To date, much attention has been paid to the growth of small and young firms in the literature (e.g., Acs, 1996; Coad, 2009). How high-growth (or fast-growing) start-ups—sometimes called "Gazelles"—contribute to the economy has often been debated (e.g., Acs & Mueller, 2008; Birch, 1981).[1] Despite their uncertain business prospects, the growth of start-up firms is an important vehicle for economic revitalization through job creation and innovation. High growth start-ups play a critical role in driving industry growth, and they presumably contribute to stimulating the stagnant economy. We expect the emergence of high growth start-ups to spur economic growth, not only in developed, but also developing economies.

When considering firm growth, some scholars emphasize the "growth of the fitter," which indicates that fitter firms survive and grow while less viable firms lose market share and exit (e.g., Coad, 2007). Put differently, growth is determined by the level of fitness in the market. Based on this perspective, it is plausible that firms with an ability to weather a turbulent environment are more likely to grow. Given that profitability represents the level of fitness in the market, we can state that firm growth is determined according to profitability. In this view, it is conceivable that profitable start-up firms are more likely to grow faster because they can adapt to the market environment. However, it remains unclear how firm growth is determined, especially for start-up firms in growing economies, because such firms are more vulnerable to turbulent economic conditions and market imperfections. Although previous studies have examined the impact on firm growth, their samples do not discriminate regarding firm age (e.g., Carpenter & Petersen, 2002; Fagiolo & Luzzi, 2006). Meanwhile, some empirical studies have provided supportive evidence on a negative relationship between firm age and growth (e.g., Evans, 1987a, 1987b). Further investigation is required to better understand the mechanism of firm growth.

This study explores the impact of profitability on the growth of start-up firms. While previous studies tend to examine firm growth, regardless of firm age, in this study, we focus on start-up firms and examine the relationship between firm growth and profitability in order to clarify firm growth during the start-up sage. By doing so, we provide insights into the relationship between firm growth and profitability over time after founding. As a result, we provide evidence that start-up firms with higher profitability increase their total assets. However, we find little evidence that profitability positively affects sales growth. In contrast, the results provide support for the notion that profitability is derived from sales growth. Furthermore, we find that firm growth depends heavily on firm age during the start-up stage.

To date, the growth of start-up firms in developed economies has been highlighted in the literature.[2] However, start-up firms in developing economies may rather

[1] For instance, by using a meta-analysis of the empirical evidence regarding whether net employment growth rather is generated by a few rapidly growing firms, Henrekson and Johansson (2010) emphasized that Gazelles create all or a large share of new net jobs and they are outstanding job creators.

[2] For instance, Wagner (1994) examined the growth of start-up firms in West Germany, and Honjo (2004) did the same in Japan.

become driving forces to promote economic growth, and they presumably play a more important role in industry growth than those in developed economies. In this respect, much attention should be paid to the growth of start-up firms in developing economies.[3] In this study, we examine firm growth using data on start-up firms in Colombia, which was considered to have a stable developing economy in the 2000s. Not surprisingly, formal financial markets for start-up firms are not well developed in developing economies, and internal financing may play a critical role in investment for business expansion. Meanwhile, high growth start-ups have a higher demand for investment in developing economies, and they may not pursue their profits during the start-up stage. We shed light on the relationship between firm growth and profitability for start-up firms in Colombia, which provides insights into how profitability, including cash flow, induces the growth of start-up firms in developing economies.

The remainder of the paper is organized as follows. Section 2 provides the research background by reviewing the related literature. Section 3 explains the analytical framework. Section 4 describes the data used in the estimation model, and the estimation results are provided in Section 5. The final section makes some concluding remarks.

RESEARCH BACKGROUND

Start-up Firm Growth

The relationship between firm size and growth has long been examined in the literature (e.g., Mansfield, 1962).[4] Due to economies of scale, smaller firms are more likely to face cost disadvantages arising from insufficient firm size. Theoretical arguments indicate that, given that the long-term average cost curve is U-shaped or L-shaped, there is a minimum efficient sale (MES) level of output in an industry. Generally, start-up firms are smaller than incumbent firms, and they pursue MES level of output to overcome cost disadvantages. However, it is difficult for start-up firms to achieve MES level at founding because of capital market imperfections. Therefore, start-up firms are more likely to face cost disadvantages (e.g., Audretsch, 1995; Caves, Khalilzadeh-Shirazi, & Porter, 1975; Weiss, 1976). It is conceivable that the probability of firm exit increases as the gap between the firm's level of output and MES level of output increases.

To compete with incumbent firms, start-up firms pursue MES level of output after entering the market. Therefore, start-up firms have strong incentives to grow faster. In other words, growth is often a prerequisite for start-up firms to survive

[3] As one of few studies researching developing economies, Coad and Tamvada (2012) examined firm growth, including start-up firms, in India.

[4] According to Gibrat's law, firm growth is independent of size. However, many empirical studies have not provided evidence on the independence between firm size and growth; Gibrat's law did not hold in these studies. Their results may rather provide support for a negative relationship between firm size and growth (e.g., Evans, 1987a, 1987b; Hall, 1987).

in the market. For this reason, firm growth is considered to be related to firm age. Indeed, some studies empirically examined the relationship between firm age and growth, and they provided supportive evidence on the negative effect of firm size and age on growth (e.g., Evans 1987a, 1987b). Based on the empirical findings, the negative effect of firm size and age on growth seems to be accepted as a stylized fact in the literature.

According to firm selection theory, start-up firms discover their abilities, including how to become efficient, through a learning process (e.g., Audrestch, 1995; Jovanovic, 1982). More precisely, firms begin on a small scale and then expand as they discover their cost functions through the process of learning, even if they do not know what their functions are. Based on the premise that capital markets are imperfect, start-up firms are more susceptible to insufficient size, even if they have high growth potential, because they face difficulties raising the necessary funds from capital markets. Conversely, start-up firms that have insufficient firm size at founding have more opportunities to grow as they learn their businesses and establish their reputations in the markets. Such firms are more likely to achieve rapid growth. According to firm selection theory advocated by Jovanovic (1982), the negative relationship between firm age and growth suggests that start-up firms grow faster to survive in the market. However, the process of learning to achieve MES level of output differs across firms, and this growth potential is heterogeneous.

Growth and Profitability Relationship

Several studies have focused on the relationship between firm growth and profitability. In a seminal work, Marris (1964) described a trade-off relationship between firm growth and profitability (or valuation). Cowling (2004) examined the short-run growth–profit trade-off of the type outlined by Marris, but the author found no evidence of this relationship. Moreover, Geroski, Machin, and Walters (1997) argued that current period firm growth rates reflect changes in current expectations about the long-run profitability of firms. Furthermore, Coad (2010) summarized the relationship between firm growth and profitability, including investment, by classifying three perspectives on firm growth: Tobin's q, imperfect market, and evolutionary theories.

To date, some studies have provided evidence on the growth and profitability relationship. For instance, Davidsson, Steffens, and Fitzsimmons (2009) showed that highly profitable and low growth firms are more likely to become highly profitable and high growth firms, and they emphasized that growth is often not a sign of sound development. Fagiolo and Luzzi (2006) found that cash flow has a positive, statistically significant effect on firm growth once they controlled for sheer size. However, Coad (2007) provided weak evidence of a positive relationship between firm growth and profitability. There is room for further research on the relationship between firm growth and profitability.

More importantly, although many empirical studies have examined firm growth, little attention has been paid to firm growth after founding. To achieve MES level of output, as discussed, start-up firms have strong incentives to grow faster. Some start-up firms have a priority to grow more rather than focus on profitability for business expansion, even if they do not obtain sufficient profits at founding. However, this priority to grow may diminish as the level of output increases over time. Therefore, it is plausible that the growth and profitability relationship varies over time, depending heavily on firm age. In this respect, research on start-up firm growth could provide critical insights into the relationship between growth and profitability.

As few exceptions, Delmar, McKelvie, and Wennberg (2013) examined the relationship between growth, profitability, and survival in new firms; they used a sample of start-up firms in Sweden. Their results showed a positive relationship between firm growth and profitability. Their findings suggest that profitable start-up firms are more likely to grow faster. However, the growth of start-up firms in developing economies may differ from that in developed economies since start-up firms have more opportunities for business expansion. Meanwhile, as Coad and Tamvada (2012) argued, formal financial markets are of limited use for start-up firms in developing economies. In this respect, start-up firms cannot necessarily rely on funds from capital markets to achieve firm growth in these economies.

In this study, we examine the relationship between firm growth and profitability using a sample of start-up firms in Colombia. As discussed later, the Colombian economy has experienced stable and rapid growth, and there is a high level of entrepreneurship in the country. Because of more opportunities for business expansion, profitability in such economies may be less important for firm growth than in developed economies, and, therefore, the reverse relationship —firm growth generating profits— may exist between firm growth and profitability.

Financing of Start-up Firms

While the effects of firm size and age on growth have been examined in the literature, other factors are considered to be more important for growth than firm size and age. Some scholars have emphasized the role of human capital—specifically entrepreneurial human capital—in the post-entry performance of firms (e.g., Cressy, 1996).[5] In addition to human capital, financial capital is of paramount importance for the growth of start-up firms: firms require financial capital to start and sustain their businesses. Without financial capital, start-up firms would not be able to invest in firm growth.

[5] It is likely that start-up firms managed by entrepreneurs with higher ability outperform those managed by entrepreneurs who have lower ability. Indeed, some studies have found the vital role of entrepreneurial human capital on the growth of start-up firms (e.g., Colombo & Grilli, 2010; Honjo, 2004). For a survey on the role of entrepreneurial human capital, see Storey and Greene (2010). However, we could not obtain information on entrepreneurs from the database used in the analysis. As such, further investigation is warranted.

To better understand the mechanism of firm growth through investment, many scholars have highlighted how investment is sensitive to internal financing, which is often measured by cash flow or operating profits (e.g., Fazzari, Hubbard, Petersen, Blinder, & Poterba,1988; Fazzari, Hubbard, & Petersen, 2000). Some scholars emphasized that profitable firms are more likely to grow because such firms can avoid financial constraints (e.g., Carpenter & Petersen, 2002; Fagiolo & Luzzi, 2006). Not surprisingly, high growth start-ups require more capital due to the growing demand for investment. In this respect, how firms finance themselves during the start-up stage will have an influence on their longevity and growth.

Many, but not all, start-up firms require funds from external capital markets when starting their businesses. For business longevity and growth, firms prefer to use internal finance stemming from cash flow because, in general, the cost of internal financing is lower than that of external financing, such as bank loans. However, it takes most firms a certain period of time after founding to gain a positive cash flow that can be used as the source of internal finance; that is, it is not easy to secure internal finance soon after founding. Despite limited internal finance, start-up firms that have high demand for growth do require large capital.

Based on the premise of capital market perfections, external finance is equivalent to internal finance; hence, internal and external finances are perfect substitutes. In this case, firms with growth potential can raise funds, regardless of internal or external finance. However, in reality, capital markets are imperfect. Despite start-up firms' growth potential, generally, external suppliers of capital, such as banks, cannot always assess growth potential, because they do not always have the knowledge and skill to assess the business. Moreover, information asymmetry between start-up firms and external suppliers of capital often arises due to the lack of start-up firms' business history and credit record. Start-up firms' performance is so uncertain that external suppliers of capital cannot accurately predict outcomes. Therefore, external suppliers of capital, such as banks, hesitate to provide funds to start-up firms because of uncertainty and information asymmetry associated with the lack of business history and credit record.

As Carpenter and Petersen (2002) argued, the principal source of the wedge of the cost of financing is due to asymmetric information between firms and potential suppliers of external capital. Such information issues often generate transaction and monitoring costs for external financing, and lead to adverse selection and moral hazard problems in capital markets, which result in agency costs associated with an increase in the cost of external financing. The cost of external financing, particularly for start-up firms, is higher than that of internal financing because of the lack of business history and credit record. In this respect, start-up firms tend to face financial constraints. Accordingly, start-up firms cannot use external finance in the same way as internal finance due to capital market imperfections.

During the start-up stage, internal finance is considered to play a critical role in firm growth. Start-up firms that can make positive profits have more financing

advantages because they face fewer financial constraints and can secure funds with lower capital costs. As such, it is conceivable that profitable start-up firms are more likely to grow faster. However, even if start-up firms face cost disadvantages for financing due to information asymmetry, such disadvantages may be mitigated when the economy is expanding. In growing economies, the role of internal finance seems to be limited for firm growth. In such economies, the emergence of start-up firms with growth potential is so attractive that external suppliers of capital can provide funds to start-up firms because of anticipated future growth. In addition, already operating firms may not easily sustain competitive advantages. Conversely, start-up firms may prefer to obtain profits by expanding their businesses and securing internal funds. By investigating start-up firms in Colombia, we provide evidence on the relationship between growth and profitability.

ANALYTICAL FRAMEWORK

Some scholars have framed firm growth based on an evolutionary economics perspective (e.g., Dosi & Nelson, 1994). Coad (2007, 2009) for example emphasized the firm selection mechanism and proposed an evolutionary model of firm growth based on the concept of replicator dynamics. Following these arguments, we consider the relationship between firm size and its variation. Let x denote firm size, and $\dot{x}$ represent the variation of firm size in a time interval. According to the perspective of evolutionary economics, we can write $\dot{x}$ as follows:

$$\dot{x} = \alpha x\left(F - \overline{F}\right) \tag{1}$$

where F is the level of fitness of the firm, $\overline{F}$ is the average level of fitness of firms in the market, and α is a parameter.

Meanwhile, other scholars have emphasized the impact of financial constraints on the post-entry performance of firms (e.g., Evans & Jovanovic, 1989). According to the perspective of financial constraints, firms prefer to use internal financing because the cost of internal financing is lower than that of external financing; this is due to information asymmetry between firms and external suppliers of capital. Following this perspective, Carpenter and Petersen (2002) proposed a model of firm growth associated with cash flow. In their model, firm growth is subject to the financial constraints that the firm faces and the variation of assets $\dot{x}_A$ in a time interval depends on the amount of cash flow, CF. Following Carpenter and Petersen's argument, we can write the derivative relationship as follows:

$$\frac{d\dot{x}_A}{dCF} = \kappa \tag{2}$$

where κ is a leverage effect of internal finance, measured by cash flow, on increase in assets. In Equation (2), the variation of assets has a linear relationship with cash flow. Dividing this relationship by the size of assets, we can consider that the growth rate of assets is a function of the ratio of cash flow to assets.

Assuming that the firm's level of fitness in Equation (1) is measured by profitability—more precisely, the ratio of cash flow to firm size—we can write the growth rate as a function of the cash flow ratio. In this case, as Coad (2009, 2010) suggested, the financial constraints perspective seems to be similar to that taken by evolutionary economics. In practice, Equation (1) is almost equivalent to Equation (2) where $\dot{x}$ is measured by assets, F is defined as CF/x, and $\alpha = \kappa$ in Equations (1) and (2).

Furthermore, we consider an estimation model of firm growth, following the evolutionary economics and financial constraints perspectives. Let $GROW_{it}\left(=\dot{x}/x\right)$ denote firm i's growth for the period $t-1$ and t. It is important to note that t indicates firm age in this study. Suppose that profitability reflects the level of firm i's fitness, which is measured by the ratio of cash flow to total assets $\left(CF/A\right)_{it}$. To identify the relationship between firm growth and the level of fitness for start-up firms, we can write the empirical model as follows:

$$GROW_{it} = \beta_0 + \beta_1 \frac{CF_{it-1}}{A_{it-1}} + \beta_2 Z_{it-1} + u_i + \nu_t + \epsilon_{it} \tag{3}$$

where β_0, β_1, and β_2 are the parameters to be estimated, and Z_{it-1} is a vector of controls.[6] The terms u_i and ν_t are firm-specific and age-specific terms, respectively, and ϵ_{it} is an error term. To avoid reverse causality, we use the lagged variable for profitability, measured by the cash flow ratio, and the vector of controls. More importantly, start-up firms have heterogeneous demands for business expansion. Using the firm-specific term u_i, we control for the heterogeneity in the demand for firm growth. Additionally, the demand for growth varies over time, and firm growth may depend on firm lifecycle associated with firm age. Thus, we control for change in the demand over time by using the age-specific term ν_t.

DATA

Colombia's Economy

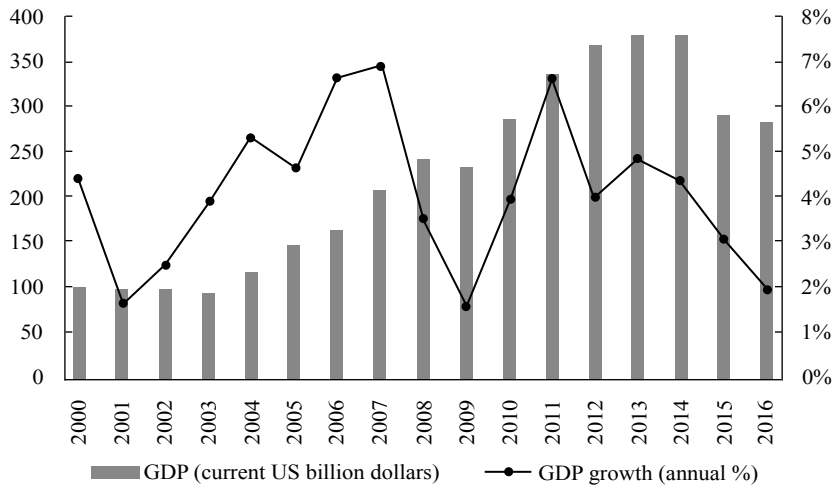
In this study, we investigate start-up firms in Colombia. Figure 1 shows Colombia's gross domestic product (GDP) as well as its annual growth rate. While

[6] Coad (2007) used multiple lagged variables for profitability in his estimation model. However, we did not, mainly because the observation period is limited in our sample.

the Colombian economy faced long-term high inflation rates until the 1990s, it achieved rapid growth around the early 2000s. The Colombian economy experienced sustained growth until the mid-2000s, but it then faced a recession after the Lehman Brothers collapse. However, while South American economies, including Brazil and Chile, recorded negative GDP growth in 2009, the Colombian economy experienced positive GDP growth. The Colombian GDP in 2011 was over 300 billion US dollars (current value), which was three times larger than that in 2000. However, the economy was sluggish in 2015 because of the decline in crude oil prices. Meanwhile, the average consumer price index has been under 10% since 2000, and inflation has recently abated.[7] Overall, the Colombian economy has recently experienced strong and sustained growth.

In Colombia, the level of entrepreneurship, which is significantly linked to the emergence of start-up firms, is higher than in most other countries. According to the Global Entrepreneurship Monitor Global Report, total early-stage entrepreneurial activity (TEA), which is often used as an index for a country's entrepreneurship level, is 22.7% in Colombia, which was ranked eighth out of sixty countries in 2015 (Kelley, Singer, & Herrington, 2016). In addition, entrepreneurial intentions are 48.2%, which puts Colombia in fourth position in the same ranking. While the entrepreneurship level is very low in some developed economies, such as Germany

Figure 1.
GDP and Annual GDP Growth in Colombia



Source: The World Bank Data.
https://data.worldbank.org/country/colombia

[7] For more details and data for Colombia and other countries, see, for example, the IMF, OECD, and World Bank websites. http://www.imf.org/external/datamapper/datasets/WEO [Accessed on November 20, 2017] http://www.oecd.org/eco/surveys/economic-survey-colombia.htm [Accessed on November 20, 2017] https://data.worldbank.org/country/colombia [Accessed on November 1, 2017]

(TEA: 4.7%), Italy (TEA: 4.9%), Spain (TEA: 5.7%), and Sweden (TEA: 7.2%), the TEA in Colombia is much higher than in these countries.[8] Further economic growth that depends on high entrepreneurship level is expected in Colombia as there are many high growth start-ups that stimulate the economy.

Sample

The data on start-up firms are from the Orbis database, which is provided by Bureau van Dijk Electronic Publishing and contains information on over 200 million privately held firms globally. Using Orbis, we obtained financial statements from 2006 to 2015. Orbis generally provides up to ten years' history of firms, and our sample includes financial statements from 2006 to 2015. In this study, we highlight firm growth during the start-up stage and target start-up firms founded in Colombia.[9] While data on firms founded in 2006 can be obtained for up to ten years, those founded in 2014 can be obtained for one or two years. In other words, the observation periods depend on when the firm was founded. To observe firm growth from founding, we target firms whose financial statements from the first accounting year are available on Orbis, and then we construct a panel data set of start-up firms for the years after they were founded. However, the longer the observation window, the smaller the number of firms. Accordingly, to secure a sufficient sample size, we measure firm growth for five years after founding, which is regarded as start-up stage in this study. As a result, our sample for start-up firms consists of panel data that contain the financial statements of firms for five years after founding (during 2006–2010).

Following Nomenclature of Economic Activities, Rev.2 (hereafter, NACE), we selected firms classified in the following industries: manufacturing (NACE code: C), construction (NACE code: F), wholesale and retail trade (NACE code: G), transportation and storage (NACE code: H), accommodation and food service activities (NACE code: I), information and communication (NACE code: J), real estate activities (NACE code: L), professional, scientific, and technical activities (NACE code: M), administrative and support service activities (NACE code: N), arts, entertainment, and recreation (NACE code: R), and other service activities (NACE code: S). However, we do not include firms classified as finance and insurance (NACE code: K) because financial statements in this industry differ from those in non-financial industries. In addition, firms classified in industries, such as agriculture, forestry, and fishing (NACE code: A), electricity, gas, steam, and air conditioning supply (NACE code: D), public administration and defence (NACE code: O), education (NACE code: P), and human health and social work activities (NACE code: Q) are not included because there are special regulations for these

[8] In general, TEA tends to be lower in developed economies, such as the European countries and Japan.

[9] The number of observations in Orbis considerably differs between countries. In practice, Orbis does not sufficiently cover start-up firms in North, Central, and South American countries, including the United States. From these countries, we obtained sufficient data on start-up firms in Colombia. This is one of the reasons why we examine firm growth focusing on start-up firms in Colombia.

industries to be incorporated. Moreover, activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (NACE code: T), and activities of extraterritorial organizations and bodies (NACE code: U) are not included in the sample.

The sample contains some firms that should be considered as outliers. First, there are some ways to legally constitute a company that is possible in the country. In this study, we only focus on public and private limited companies, mainly because these are the standard company form in most countries. Second, extremely large firms are excluded from the sample. More precisely, firms whose equity finance is no less than 20 billion pesos at founding are regarded as outliers.[10] Third, only a few firms have extremely low or high cash flow ratios, and, therefore, the variable for the cash flow ratio is winsorized at 1% and 99%. Fourth, we construct balanced panel data for five years after founding to identify the growth process over time. Therefore, firms whose financial statements are not available for five years are excluded from the sample.[11] Furthermore, several firms are not independent, and they appear to be subsidiaries and affiliated firms. Such firms have different growth strategies from independent firms. Therefore, in the estimation, we control for the impact of firm-specific characteristics on firm growth using firm-specific terms. To check robustness, we also estimate the determinants of firm growth by excluding non-independent firms from the sample.

Regarding the performance of start-up firms, we capture firm growth over time. As discussed, we measure firm growth for five years after founding. To control for the difference in inflation rates over time, we use GDP deflators when calculating firm growth.[12] The variables for financial statements, except for ratio measures, are normalized by GDP deflators based on 2006 values.

The sample consists of 3264 firms founded during 2006-2010. The data on financial statements for five years after founding are available. In the Appendix, Table A1 describes the distribution of start-up firms by industry. The proportion of start-up firms in wholesale and retail trade (NACE code: G) is over 30%, while the proportion of start-up firms in manufacturing (NACE code: C) accounts for 17%. The mean sales are approximately 6 billion pesos, and the median sales are approximately 0.3 billion pesos in the first accounting year. Moreover, the mean total assets are approximately 4 billion pesos, and the median total assets are approximately 0.2 billion pesos in the first accounting year in the sample.

[10]According to annual exchange rates reported in OECD, 1 US dollar equaled 2361.139 Colombia pesos in 2006. 20 billion pesos had a value of approximately 9 million US dollars based on this exchange rate. See exchange rates (indicator) by OECD. doi: 10.1787/037ed317-en [accessed on October 31, 2017]

[11]In this study, we do not examine firm exit among start-up firms. Further investigation is required to better understand the survival and exit of start-up firms in Colombia.

[12]We obtained GDP deflators for Colombia from the World Bank website. https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?locations=CO [accessed on September 30, 2017]

Variables

In this study, we measure firm growth using the annual growth rates of sales and total assets. Firm growth is defined as the differences in the logarithms of sales or total assets between two consecutive years.[13] Table 1 describes the descriptive statistics of firm growth by firm age. Table 1 reveals that the mean and median growth rates of sales and total assets are always positive for five years after founding. We find that, on average, start-up firms are more likely to grow after founding. In particular, the mean growth rate of sales is over 50% from the first to the second accounting year. However, the mean growth rate, regardless of sales or total assets, gradually decreases with firm age. The mean comparison test and Wilcoxon singed-rank test indicate that the growth rates significantly decrease in comparison to those in the previous years.

Table 1.
Sales Growth and Asset Growth of Start-up Firms

Sales growth								
Age	**Mean**	**SD**	**5%**	**Median**	**95%**	|*t*|	|*z*|	*N*
1 => 2	0.506	1.096	–0.814	0.343	2.404	-----	-----	3264
2 => 3	0.145	0.894	–1.016	0.116	1.320	13.205***	18.196***	3264
3 => 4	0.105	0.777	–0.921	0.087	1.239	1.734*	4.454***	3264
4 => 5	0.061	0.750	–0.987	0.064	0.989	2.090**	4.634***	3264
All	0.204	0.907	–0.951	0.128	1.600			13056
Asset growth								
Age	**Mean**	**SD**	**5%**	**Median**	**95%**	|*t*|	|*z*|	*N*
1 => 2	0.320	0.683	–0.478	0.228	1.428	-----	-----	3264
2 => 3	0.174	0.594	–0.577	0.115	1.119	8.631***	10.466***	3264
3 => 4	0.153	0.523	–0.541	0.106	0.950	1.425	2.555**	3264
4 => 5	0.113	0.504	–0.568	0.073	0.859	2.972***	4.063***	3264
All	0.190	0.586	–0.541	0.123	1.134			13506

Notes: SD indicates the standard deviation. |*t*| indicates statistics for paired mean comparison test with the previous year's values. |*z*| indicates statistics for the Wilcoxon singed-rank test with the previous year's values. *N* indicates the number of firms.

Source: Author's own elaboration based on Orbis database.

[13]Many studies have measured employment growth (Evans, 1987a, 1987b). However, we did not use this growth measurement, because we did not obtain data on the number of employees from Orbis.

The definitions of variables used in the estimation model are shown in Table 2. While the growth rates of sales and total assets are used as dependent variables, the cash flow ratio and firm age are used as major independent variables in the estimation model. Table 3 provides the descriptive statistics of cash flow ratios by firm age. We find that the mean and median cash flow ratios are always positive in Table 3. While the mean cash flow ratio is the highest in the second accounting year, it subsequently decreases.

Considering other variables, we control for differences in asset structure, including tangibility, across start-up firms, and include the fixed asset ratio variable in the estimation model, following previous studies (e.g., Claessens, Erik Feijen, & Laeven, 2008; Frank & Goyal, 2003). In addition, following Coad (2007), we control for firm size. Moreover, we use GDP growth to control for macroeconomic conditions because start-up firms may be vulnerable to economic growth and, as shown in Figure 1, the economic growth in Colombia does differ during the observation period. It is important to note that *t* indicates firm age in this study. While

Table 2.
Definitions of Variables

Variable	Symbol	Definition
Sales growth	*GROW_S*	Difference in the logarithm of net sales between two subsequent years
Asset growth	*GROW_A*	Difference in the logarithm of total assets between two subsequent years
Cash flow ratio	*CF/A*	Operating profits plus financial profits minus tax, divided by total assets
Fixed asset ratio	*FA/A*	Total amount (after depreciation) of non-current assets (Sum of intangible assets, tangible assets, and other fixed assets), divided by total assets
Sales size	*SIZE_S*	Logarithm of net sales
Asset size	*SIZE_A*	Logarithm of total assets
GDP growth	*GDP*	Annual growth rate of GDP
Firm age	*AGE*2	Dummy for the second accounting year (reference category)
	*AGE*3	Dummy for the third accounting year
	*AGE*4	Dummy for the fourth accounting year
	*AGE*5	Dummy for the fifth accounting year

Notes: All data on financial statements are measured in the local currency (millions of Colombian pesos) normalized by GDP deflators.

Source: Author's own elaboration.

Table 3.
Start-up Firms' Cash Flow Ratio

Cash flow ratio								
Age	**Mean**	**SD**	**5%**	**Median**	**95%**	|*t*|	|*z*|	*N*
1	0.141	0.274	–0.136	0.081	0.583	-----	-----	3264
2	0.145	0.271	–0.108	0.090	0.571	0.607	1.708*	3264
3	0.133	0.250	–0.107	0.083	0.532	2.202**	2.299**	3264
4	0.127	0.236	–0.116	0.083	0.500	1.339	2.206**	3264
5	0.122	0.224	–0.095	0.077	0.480	1.105	1.909*	3264
All	0.133	0.252	–0.111	0.083	0.530			16320

Notes: SD indicates the standard deviation. |*t*| indicates statistics for paired mean comparison test with the previous year's values. |*z*| indicates statistics for Wilcoxon singed-rank test with the previous year's values. *N* indicates the number of firms.
Source: Author's own elaboration based on Orbis database.

GDP growth depends on the year, founding years differs for each firm. Therefore, the GDP growth variable depends not only on age *t*, but also on firm *i*. Furthermore, dummies for firm age are included to control for differences in firm growth according to firm lifecycle. Table 4 provides the descriptive statistics of variables used in the estimation model.

ESTIMATION RESULTS

Sales Growth

Table 5 presents the estimation results for sales growth. In Table 5, we use fixed-effects estimation for panel data to consider heterogeneity across firms and estimate the determinants of firm growth. We show the estimation results in column (i) of Table 5 when the variables for the cash flow ratio, fixed-assets ratio, GDP growth, and firm age are included. We also show the estimation results in column (ii) when including the lagged sales size instead of the dummies for firm age. Several firms are not independent and appear to be subsidiaries and affiliated firms. In addition, firms in the construction and real estate industries may be significantly associated with the economic growth cycle. Therefore, we show the estimation results in columns (iii) when non-independent firms and those classified as these industries are excluded from the sample. Moreover, to check for robustness, columns (iv) and (v) present the estimation results when alternative estimation methods are employed. While the ordinary least squares method is applied to estimate coefficients in columns (iv), instrumental variables and the two-stage least squares method for panel data is applied to the estimation in columns (v) because of the

Table 4.
Descriptive Statistics of Variables

Symbol	Mean	SD	5%	Median	95%	*NT*
GROW_S	0.204	0.907	–0.951	0.128	1.600	13056
GROW_A	0.190	0.586	–0.541	0.123	1.134	13056
CF/A	0.136	0.258	–0.115	0.084	0.549	13056
FA/A	0.284	0.290	0.000	0.181	0.892	13056
SIZE_S	6.046	1.864	3.129	5.958	9.285	13056
SIZE_A	5.696	1.954	2.711	5.598	9.173	13056
GDP	0.042	0.018	0.017	0.040	0.069	13056

Notes: SD indicates the standard deviation. *NT* indicates the number of observations. The descriptive statistics of *GROW_S*, *GROW_A*, and *GDP* are measured during the period between 2 to 5 years of firm operation. The descriptive statistics of *CF/A*, *FA/A*, *SIZE_S*, and *SIZE_A* are measured during the period between 1 to 4 years of firm operation
Source: Author's own elaboration based on Orbis database.

endogeneity issue of the cash flow ratio.[14] In column (v), the cash flow ratio is regarded as endogenous, and a one-year lagged variable for the cash flow ratio is used as an instrumental variable.

With respect to the growth and profitability relationship, the coefficients of the cash flow ratio are negative and significant for sales growth in columns (i)–(iv) of Table 5. The results do not show that the cash flow ratio has a positive effect on sales growth.[15] We find no evidence on cash flow sensitivity for the sales growth of start-up firms. The results indicate that less profitable start-up firms are more likely to increase their sales, suggesting that profitability measured by the current cash flow, although it is the source of shareholder's equity increase, does not reflect the firm's level of fitness. Even though start-up firms have more cash flow, they do not always increase their sales. While the negative relationship between firm growth and profitability is not consistent with Delmar et al.'s (2013) findings, this relationship is in part consistent with Coad's (2007) findings, which suggest that cash flow plays a limited role in sales growth in growing economies, such as Colombia. Start-up firms with few profits may rather increase their sales, presumably because they have growth opportunities and incur higher investment costs.

Regarding other variables, the fixed asset ratio has a positive effect on sales growth, and its coefficients are significant in Table 5. The results indicate that start-up firms

[14]Coad (2007) used two and three-year lagged variables for profitability. This study does not use these, however, to ensure sufficient sample size because our sample covers variables only for five years.

[15]Instead of fixed-effects estimation, we employ random-effects estimation for panel data. As a result, we find support for a positive relationship between asset growth and profitability, and a negative relationship between sales growth and profitability.

Table 5.
Estimation Results for Sales Growth ($GROW\_S_{it}$)

Variable	(i)	(ii)	(iii)	(iv)	(v)
	FE	**FE**	**FE**	**OLS**	**IV**
$(CF/A)_{it-1}$	–0.457***	–0.067*	–0.464***	–0.295***	0.048
	(0.054)	(0.036)	(0.071)	(0.034)	(0.109)
$(FA/A)_{it-1}$	0.262***	0.012	0.372***	0.094***	0.112***
	(0.065)	(0.049)	(0.081)	(0.031)	(0.028)
$SIZE\_S_{it-1}$		–0.842***			
		(0.015)			
GDP_{it-1}	1.746***	2.217***	2.196***	1.757***	1.887***
	(0.572)	(0.386)	(0.712)	(0.539)	(0.608)
$AGE3_{it-1}$	–0.364***		–0.361***	–0.365***	
	(0.027)		(0.033)	(0.024)	
$AGE4_{it-1}$	–0.422***		–0.376***	–0.420***	–0.052**
	(0.024)		(0.029)	(0.024)	(0.023)
$AGE5_{it-1}$	–0.475***		–0.447***	–0.471***	–0.102***
	(0.023)		(0.028)	(0.023)	(0.021)
Industry dummies	No	No	No	Yes	No
Number of observations	13056	13056	8056	13056	9792
Number of firms	3264	3264	2014	3264	3264
F statistics	87.4***	788.5***	50.9***	31.3***	
Wald statistics					47.3***

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. OLS indicates pooled-OLS estimation. IV indicates instrumental variables and two-stage least squares method when $(CF/TA)_{it-1}$ is endogenous and its lagged variable is used as an instrumental variable. In column (iii), non-independent firms and firms classified as construction or real estate activities are excluded from the sample. For firm age, $AGE2_t$ is the reference category in columns (i)–(iv), and $AGE3_t$ is the reference category in columns (v). Industry dummies are dummies measured by the NACE codes shown in Figure 1.

Source: Author's own elaboration based on Orbis database.

with a higher fixed asset ratio are more likely to increase their sales. In addition, firm size has a negative effect on sales growth, which is consistent with Gibrat's law. More importantly, the coefficients of GDP growth are positive, and GDP growth has a positive effect on sales growth. The results reveal that start-up firms

tend to increase their sales during the economic boom period.[16] Furthermore, the dummies for firm age are negative and significant for sales growth in Table 5. Table 1 showed that the mean and median growth rates of sales and total assets are positive during the observation period, and Table 5 presents empirical evidence on the effect of firm age on sales growth. In the regression model, we find that firm growth depends heavily on firm age during the start-up stage, which is consistent with the trends of firm growth shown in Table 1. The results reveal that firm growth varies over time after founding, depending on firm lifecycle. More specifically, the estimation results indicate that firm growth decreases with firm age, partly because younger firms tend to have stronger incentives to grow faster; this provides support for the learning process discussed in the literature (e.g., Audrestch, 1995; Jovanovic, 1982).

As a result, our findings do not support the positive effect of profitability on sales growth for start-up firms in Colombia. However, start-up firms may generate more cash flow through the growth process, and, therefore, the reverse relationship may occur in sales growth. Following Coad (2007), we examine the reverse relationship between firm growth and profitability. The cash flow ratio is used as the dependent variable, and sales growth is used as the independent variable. The variable for GDP growth and dummies for firm age are also included in the estimation model. Table 6 provides the estimation results for profitability. We show the estimation results when the variables for sales growth, GDP growth, and the dummies for firm age are included in column (i) of Table 6. Non-independent firms and those classified as construction and real estate activities are excluded from the sample in column (ii).

As shown in Table 6, the coefficients of sales growth are positive and significant, indicating that sales growth induces profitability. We find a positive relationship between sales growth and profitability when estimating the regression model for profitability, which is consistent with the findings of Coad (2007) and Cowling (2004). The results indicate that start-up firms that achieve rapid sales growth tend to yield more profits, suggesting that profitability is derived from sales growth. This may imply that financial constraints can be mitigated through the learning process associated with sales expansion.

Asset Growth

In addition to sales growth, we estimate the growth and profitability relationship when measuring firm growth by the growth rate of total assets. Similar to Table 5, Table 7 presents the estimation results for asset growth. In Table 7, the positive

[16] As GDP growth has a positive effect on sales growth, the growth and profitability relationship may depend on economic growth cycle, such as booms and recessions. Therefore, we estimate the determinants of firm growth when dividing the sample by founding year. The estimation results for sales growth and asset growth are provided in Tables A2 and A3 of the Appendix, respectively. As a result, we find that the sales growth and profitability relationship tends to be weak for firms founded in 2009 and 2010.

Table 6.
Estimation Results for the Effects of Sales Growth on Profitability ($(CF / A)_{it-1}$)

Variable	(i)	(ii)
	FE	**FE**
$GROW\_S_{it}$	0.024***	0.027***
	(0.002)	(0.004)
GDP_{it}	0.142	0.259
	(0.131)	(0.173)
$AGE3_t$	–0.003	–0.004
	(0.005)	(0.007)
$AGE4_t$	–0.009*	–0.014**
	(0.006)	(0.007)
$AGE5_t$	–0.014**	–0.013*
	(0.006)	(0.007)
Number of observations	13056	8056
Number of firms	3264	2014
F statistics	23.1***	13.4***

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. In column (ii), non-independent firms and firms classified as construction or real estate activities are excluded from the sample. For firm age, $AGE2_t$ is the reference category in all columns.
Source: Author's own elaboration based on Orbis database.

relationship between asset growth and profitability is supported even when alternative estimation methods are employed. We find that the cash flow ratio has a positive effect on asset growth, while it has a negative effect on sales growth, as shown in Table 5. The results reveal that start-up firms with higher profitability are more likely to increase their assets in Colombia, partly because retained earnings together with profitability results in an equity increase for shareholders. The findings about the positive effect of profitability on asset growth are consistent with Carpenter and Petersen's (2002) findings, although the impact (coefficient) of profitability is much smaller than their estimated impact. This may imply that start-up firms tend to increase capital by means other than retaining earnings.

Regarding other variables, the coefficients of the fixed asset ratio are, in part, positive, which are consistent with those shown in Table 5. The results indicate that start-up firms with a higher fixed asset ratio are more likely to increase their total assets. Moreover, we find that GDP growth has a significant effect on asset growth, whereas the coefficients of GDP growth for asset growth tend to be lower than those for sales growth. Furthermore, the dummies for firm age are negative and significant for asset growth, which are consistent with those shown in Table 5.

Table 7.
Estimation Results for Asset Growth ($GROW\_A_{it}$)

Variable	(i)	(ii)	(iii)	(iv)	(v)
	FE	**FE**	**FE**	**OLS**	**IV**
$(CF/A)_{it-1}$	0.216***	0.073***	0.198***	0.191***	0.360***
	(0.037)	(0.028)	(0.043)	(0.025)	(0.069)
$(FA/A)_{it-1}$	0.090*	0.034	0.149***	–0.023	0.007
	(0.050)	(0.033)	(0.056)	(0.020)	(0.020)
$SIZE\_A_{it-1}$		–0.657***			
		(0.016)			
GDP_{it}	0.713***	1.887***	0.758*	1.013***	1.033***
	(0.355)	(0.270)	(0.438)	(0.346)	(0.398)
$AGE3_t$	–0.148***		–0.146***	–0.149***	
	(0.017)		(0.021)	(0.016)	
$AGE4_t$	–0.172***		–0.169***	–0.174***	–0.024
	(0.015)		(0.018)	(0.015)	(0.015)
$AGE5_t$	–0.212***		–0.204***	–0.215***	–0.064***
	(0.015)		(0.019)	(0.015)	(0.014)
Industry dummies	No	No	No	Yes	No
Number of observations	13056	13056	8056	13056	9792
Number of firms	3264	3264	2014	3264	3264
F statistics	43.8***	409.4***	28.5***	20.2***	
Wald statistics					55.6***

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. OLS indicates pooled-OLS estimation. IV indicates instrumental variables and two-stage least squares method when $(CF/TA)_{it-1}$ is endogenous and its lagged variable is used as an instrumental variable. In column (iii), non-independent firms and firms classified as construction or real estate activities are excluded from the sample. For firm age, $AGE2_t$ is the reference category in columns (i)–(iv), and $AGE3_t$ is the reference category in columns (v). Industry dummies are dummies measured by the NACE codes shown in Figure 1.

Source: Author's own elaboration based on Orbis database.

As shown in Table 8, the coefficients of asset growth are negative, indicating that start-up firms that achieve higher asset growth are less likely to create profits. While internal financing in accordance with profitability increases assets, as shown in Table 7, asset growth does not exert an influence on profitability. The findings

imply that investment does not necessarily lead to profitability for start-up firms. In this respect, the importance of financial constraints associated with investment seems to be exaggerated for start-up firms, although financial constraints may essentially impede business start-ups. However, in our analysis, we focus on the short-run growth-profit trade-off —more precisely, asset growth in the five years after founding— and it may take start-up firms a longer period to secure profits by investment. Further investigation, including long-term profits, would be required to elucidate the asset growth and profitability relationship.

CONCLUSIONS

This study has explored the impact of profitability on the growth of start-up firms. Using data on start-up firms in Colombia, we examined the relationship between firm growth and profitability measured by the cash flow ratio. We provided evidence that

Table 8.
Estimation Results for the Effects of Asset Growth on Profitability ($(CF/A)_{it-1}$)

Variable	(i)	(ii)
	FE	FE
$GROW\_A_{it}$	–0.012**	–0.008
	(0.005)	(0.006)
GDP_{it}	0.194	0.324*
	(0.132)	(0.173)
$AGE3_t$	–0.014***	–0.015**
	(0.005)	(0.007)
$AGE4_t$	–0.022***	–0.025***
	(0.006)	(0.007)
$AGE5_t$	–0.028***	–0.026***
	(0.006)	(0.008)
Number of observations	13056	8056
Number of firms	3264	2014
F statistics	5.0***	3.0**

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. In column (ii), non-independent firms and firms classified as construction or real estate activities are excluded from the sample. For firm age, $AGE2_t$ is the reference category in all columns.

Source: Author's own elaboration based on Orbis database.

start-up firms with higher profitability increase their total assets. However, we found little evidence that profitability positively affects sales growth for start-up firms. In contrast, the results provided support for the notion that profitability is derived from sales growth. We also found that firm growth depends heavily on firm age during the start-up stage, suggesting that sales growth depends on firm lifecycle. Our findings imply that start-up firms expand their businesses without internal financing in growing economies such as Colombia, and that they can generate internal finance through their sales growth.

There are, however, limitations to this study. First, we did not identify whether the relationship between firm growth and profitability is derived from firm selection or financial constraints. Second, we prioritised tracing firm growth during the period from the first to the fifth accounting year, and we did not consider firm exit. Third, we did not examine the effects of market conditions and competition on firm growth and profitability, even though start-up firms would be susceptible to market conditions and competition. Fourth, we did not examine the growth of start-up firms in other countries, and a positive relationship between sales growth and profitability may be evident only in Colombia. Different findings may arise in stagnant economies, such as some European countries and Japan. Further investigation is required to better understand how the growth of start-up firms is determined in various developed and developing economies.

Despite the study's limitations, we provide some insights into firm growth during the start-up stage. Our findings provide supportive evidence that firm growth depends heavily on firm age. In particular, the findings of this study suggest that start-up firms do not increase their sales by means of profitability; they do, however, increase their assets through retained earnings in accordance with profitability. The findings also suggest that the mechanism of sales growth differs from that of asset growth for start-up firms. In addition, sales growth generates profitability for start-up firms. To sustain new businesses, as the findings of this study suggest, firms should seek sales growth during the start-up stage. Moreover, as economic growth is found to be related to the sales growth of start-up firms, potential entrepreneurs should pay more attention to macroeconomic conditions. Furthermore, we contribute by providing new evidence on the growth and profitability relationship in Colombia. Little previous attention has been paid to the growth of start-up firms in developing economies.

There are several implications as a result of the findings of this study. To date, policy support for potential entrepreneurs and small businesses has often been enacted for mitigating financial constraints in many countries. Essentially, some scholars have emphasized the existence of financial constraints (e.g., Carpenter and Petersen, 2002; Fazzari et al., 1988). However, as Coad (2009) argued, the issue of financial constrains impeding firm growth may be exaggerated. In practice, the results do not demonstrate that the cash flow ratio induces sales growth, even though business start-ups generally tend to be financially constrained. In Santarelli and Vivarelli's (2007) opinion, firms' post-entry performance, includ-

ing survival/failure and growth, should be seen as socially optimal rather than the result of either financial market imperfections or other market failures. Firms with higher capabilities may not only be able to increase their sales but also to secure internal finance. Our findings imply that sales growth depends on firm lifecycle rather than on the level of cash flow during the start-up stage. Paying attention to a firm's dynamic change over time would be more useful to understand the post-entry performance of firms in growing economies.

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APPENDIX

Table A1 describes the distribution of start-up firms by industry. Tables A2 and A3 show the estimation results for sales growth and asset growth, respectively, when we divide the sample by founding year. It is important to note that columns (iv) include firms founded in 2009 and 2010 because the number of observations for 2010 is small (only 260).

Table A1.
Distribution of Start-up Firms by Industry

NACE	Industry	*N*	(%)
C	Manufacturing	549	(16.8)
F	Construction	325	(10.0)
G	Wholesale and retail trade	1026	(31.4)
H	Transportation and storage	142	(4.4)
I	Accommodation and food service activities	56	(1.7)
J	Information and communication	225	(6.9)
L	Real estate activities	165	(5.1)
M	Professional, scientific, and technical activities	537	(16.5)
N	Administrative and support service activities	187	(5.7)
R	Arts, entertainment, and recreation	16	(0.5)
S	Other service activities	36	(1.1)
	Total	3264	(100.0)

Notes: *N* indicates the number of firms. NACE indicates the NACE version 2 main section.
Source: Author's own elaboration based on Orbis database.

Table A2.
Estimation Results for Sales Growth by Founding Year ($GROW\_S_{it}$)

Variable	(i)	(ii)	(iii)	(iv)
	2006	**2007**	**2008**	**2009–2010**
	FE	**FE**	**FE**	**FE**
$(CF/A)_{it-1}$	–0.516***	–0.563***	–0.517***	–0.173
	(0.111)	(0.108)	(0.093)	(0.117)
$(FA/A)_{it-1}$	0.260**	0.232	0.310***	0.241
	(0.117)	(0.148)	(0.114)	(0.148)
$AGE3_t$	–0.376***	–0.320***	–0.372***	–0.373***
	(0.047)	(0.051)	(0.061)	(0.055)
$AGE4_t$	–0.423***	–0.367***	–0.425***	–0.408***
	(0.045)	(0.047)	(0.047)	(0.052)
$AGE5_t$	–0.393***	–0.463***	–0.521***	–0.425***
	(0.042)	(0.045)	(0.046)	(0.053)
Number of observations	3392	3476	3744	2444
Number of firms	848	869	936	611
F statistics	28.1***	27.7***	36.0***	18.3***

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. For firm age, $AGE2_t$ is the reference category.
Source: Author's own elaboration based on Orbis database.

Table A3.
Estimation Results for Asset Growth by Founding Year ($GROW\_A_{it}$)

Variable	(i)	(ii)	(iii)	(iv)
	2006	**2007**	**2008**	**2009–2010**
	FE	**FE**	**FE**	**FE**
$(CF/A)_{it-1}$	0.179***	0.231***	0.182***	0.291***
	(0.069)	(0.069)	(0.062)	(0.101)
$(FA/A)_{it-1}$	0.108	0.282**	0.011	–0.052
	(0.097)	(0.120)	(0.075)	(0.109)
$AGE3_t$	–0.154***	–0.143***	–0.135***	–0.156***
	(0.035)	(0.032)	(0.033)	(0.033)
$AGE4_t$	–0.143***	–0.167***	–0.169***	–0.194***
	(0.029)	(0.029)	(0.028)	(0.033)
$AGE5_t$	–0.178***	–0.218***	–0.201***	–0.228***
	(0.029)	(0.028)	(0.027)	(0.033)
Number of observations	3392	3476	3744	2444
Number of firms	848	869	936	611
F statistics	9.5***	15.5***	14.6***	13.0***

Notes: Figures in parentheses are robust standard errors. ***, **, and * indicate the 1%, 5%, and 10% significance levels, respectively. FE indicates fixed-effects estimation. For firm age, $AGE2_t$ is the reference category.
Source: Author's own elaboration based on Orbis database.

ARTÍCULO

CUSTOMER PERCEIVED VALUE IN HIGH GROWTH FIRMS

Suzanne Mawson

Mawson, S. (2019). Customer perceived value in high growth firms. *Cuadernos de Economía*, *37*(75), 755-778.

Scholars have asserted that a key factor that differentiates high growth firms (HGFs) from other firms is their ability to create value for their customers. This paper contributes to the literature by empirically exploring this relationship. Drawing on comparative cohorts of eleven HGFs and ten non-HGFs in Scotland, this paper finds that the HGFs were much more likely than their non-HGF counterparts to be positively influencing customer perceived value, which is considered as an important enabler of firm performance and growth. In addition to its empirical contribution to the high growth entrepreneurship literature, this paper raises issues for future research.

Keywords: High growth firms, HGF, entrepreneurship, customer perceived value, value creation.
JEL: L25; L26; M13; M31.

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Suggested citation: Mawson, S. (2019). Customer perceived value in high growth firms. *Cuadernos de Economía, 37*(75), 755-778. doi: 10.15446/cuad.econ.v37n75.68913

Este artículo fue recibido el 20 de noviembre de 2017, ajustado el 01 de marzo de 2018, y su publicación aprobada el 05 de marzo de 2018.

Mawson, S. (2019). Valor percibido por el cliente en empresas de alto crecimiento. *Cuadernos de Economía*, 37(75), 755-778.

La comunidad académica ha afirmado que un diferenciador clave de las empresas de alto crecimiento (EAC) es su capacidad para crear valor para sus clientes. Este artículo contribuye a la literatura al explorar de manera empírica esta relación. Basándose en cohortes comparativos de 11 ECA y 10 no-EAC en Escocia, este artículo concluye que las EAC eran mucho más propensas que las no-EAC a la hora de influir positivamente en el valor percibido por el cliente, cuya creación se considera un activador importante de rendimiento y crecimiento de empresas. Además de su contribución empírica a la literatura de emprendimiento de alto crecimiento, este artículo plantea futuras líneas de investigación.

Palabras clave: empresa de alto crecimiento, HGF, emprendimiento, valor percibido por el cliente, creación de valor.
JEL: L25; L26; M13; M31.

Mawson, S. (2019). Valeur perçue par le client dans les entreprises à forte croissance. *Cuadernos de Economía*, 37(75), 755-778.

La communauté académique a déclaré qu'un facteur distinctif essentiel des entreprises à forte croissance (EAC) est leur capacité à créer de la valeur pour leurs clients. Cet article contribue aux publications sur le sujet par une exploration empirique de cette relation. Se basant sur des ensembles comparatifs de 11 EAC et 10 non-EAC en Ecosse, il conclut que les EAC ont bien davantage tendance que les non-EAC à influer positivement sur la valeur perçue par le client, dont la création est considérée comme un activateur important de rendement et de croissance d'entreprises. Outre sa contribution empirique aux publications sur l'entrepreunariat à forte croissance, cet article propose de futures directions de recherche.

Mots-clefs: entreprise à forte croissance, HGF, entreprenariat, valeur perçue par le client, création de valeur.
JEL: L25; L26; M13; M31.

Mawson, S. (2019). Valor percebido pelo cliente em empresas de alto crescimento. *Cuadernos de Economía*, 37(75), 755-778.

A comunidade acadêmica afirmou que o principal diferencial das empresas de alto crescimento (EAC) é sua capacidade de criar valor para seus clientes. Este artigo contribui para a literatura explorando empiricamente essa relação. Baseado em coortes comparativas de 11 EAC e 10 não-EAC na Escócia, este artigo conclui que as EAC eram muito mais propensas do que as não-EAC a influenciar positivamente o valor percebido pelo cliente, cuja criação é considerada um importante fator de desempenho e crescimento das empresas. Além de sua contribuição empírica para a literatura de empreendedorismo de alto crescimento, este artigo propõe futuras linhas de pesquisa.

Palavras-chave: empresa de alto crescimento, HGF, empreendedorismo, valor percebido pelo cliente, criação de valor.
JEL: L25; L26; M13; M31.

INTRODUCTION

The past twenty years have seen 'high growth firms' (henceforth HGFs) become increasingly important,[1] particularly within North America and Europe where these organisations are recognised as major job creators (Coad, Daunfeldt, Hölzl, Johansson, & Nightingale, 2014a; Henrekson & Johansson, 2010) and key contributors to wider economic development and growth (Anyadike-Danes, Hart, & Du, 2015; Lee, 2014). Researchers have sought to understand many of the facets of high growth entrepreneurship including the age and traits of the entrepreneur (Barringer, Jones, & Neubaum, 2005; Brüderl & Preisendörfer, 2000; Nicholls-Nixon, 2005), the geography of high growth firms (Brown & Mawson, 2016; Mason, Brown, Hart, & Anyadike-Danes, 2015; Rice, Lyons, & O'Hagan 2015), the nature of firm growth and the growth process (Brown & Mawson, 2013; Garnsey, Stam, & Heffernan, 2006), productivity (Daunfeldt, Elert, & Johansson, 2014; Du and Temouri, 2015), innovation activity (Coad & Rao, 2008; Segarra & Teruel, 2014), financing (Brown & Lee, 2014; Lee, 2014; Mohr, Garnsey, & Theyel, 2014) and, more recently, the sustainability of rapid growth and HGFs (Daunfeldt & Halvarsson, 2015; Satterthwaite & Hamilton, 2017).

Despite this abundance of research, our understanding of high growth remains limited, particularly in terms of firm-specific dynamics, processes, and behaviours, which are often overlooked in favour of larger aggregate studies that 'count' or 'measure' HGFs. As scholars have noted, high growth is a temporary phenomenon or state (Brown & Mawson, 2013; Brown, Mawson, & Mason, 2017) rather than a permanent characteristic of firms; however, the literature largely fails to explore actions and behaviours at firm level and how those may contribute to rapid growth. Some studies have briefly acknowledged the role of elements such as founder capabilities (Goedhuys & Sleuwaegen, 2010) and growth intentions (Stenholm, 2011), business strategy (Barringer et al., 2005), and operational flexibility (Hansen & Hamilton, 2011), but the literature has largely overlooked how such elements may differentiate HGFs from their slower-growth counterparts.

Within the marketing literature, it is widely recognised that creating value for customers acts as a significant competitive advantage and source of superior financial performance for firms (O'Cass & Ngo, 2011; Sirmon, Hitt, & Ireland, 2007). High growth entrepreneurship scholars have, for some time, observed that HGFs appear to differ from other firms due to their ability to create unique value for their

[1] The OECD defines a HGF as "an enterprise with average annualised growth (in number of employees or turnover) greater than 20% per annum over a three-year period, with a minimum of 10 employees at the beginning of the growth period" (Eurostat-OECD, 2008, p. 61). There has been substantial debate on definitional issues, particularly on the merits of the OECD definition and measurement criteria as well as the potential measurement bias that arises from focusing on either turnover or employees (see Daunfeldt, Johansson, & Halvarsson, 2015 for a comprehensive review). This study chose to measure HGFs in terms of turnover growth, which is in line with recent studies (e.g. Brown & Mawson 2016; Kidney et al., 2017) as well as how many firms themselves conceptualise growth (see Achtenhagen, Naldi, & Melin, 2010; Robson & Bennett, 2000).

customers (Barringer et al., 2005; Birley & Westhead, 1990; Kim & Mauborgne, 1997; Smallbone, Leigh, & North, 1995; Zhang, Yang, & Ma 2008). Surprisingly, however, these often anecdotal observations have not been rigorously explored. Recently, Chandler, Broberg, & Allison, (2014) have usefully investigated the issue of value propositions -how firms communicate their competitive advantage- as a differentiator between HGFs and non-HGFs in declining industries. However, their business model framing failed to fully address the underlying issue of *customer perceived value*, which is critical not only for the creation of value propositions, but also for fully understanding the nature of value creation activities within HGFs. As such, observations of HGFs as value creators remain anecdotal.

Taking this gap into consideration, this paper makes an important contribution to the high growth entrepreneurship literature by empirically exploring the issue of customer value creation within the context of HGFs. Drawing on depth interview data from comparative cohorts of HGFs and non-HGFs in Scotland, this paper addresses the following research question: *Is the creation of customer perceived value a differentiating characteristic of HGFs?*

The paper is structured as follows: The first section assesses the literature on high growth firms contextualised in the value creation literature and presents a theoretical model of value creation. The second outlines the methodology utilised during the course of this study. The third presents empirical findings from the research, which are then discussed in detail in the following section. The final section identifies some conclusions and areas for future research.

HIGH GROWTH ENTREPRENEURSHIP AND VALUE CREATION

As previously noted, empirical research on HGFs has been gaining momentum; the result is that there is now a substantial body of knowledge from a variety of perspectives. Indeed, Coad et al. (2014a) observe that the number of papers published in this area have quadrupled since 1990, which attests to the significant (and still increasing) appeal of HGFs for researchers. As the field has developed, so too has the nature of empirical studies. Particularly, over the past five years, there has been a gradual shift away from the 'inventory' or 'catalogue' type studies that comprised some of the early literature (e.g. Delmar, Davidsson, & Gartner 2003; Stam, 2005) in favour of more focused and nuanced investigations of high growth entrepreneurship that examine a range of issues including the macroeconomic environment (Teruel & de Wit, 2011), internationalisation (Brown & Mawson, 2016), and business practices and strategies (Coad, Daunfeldt, Hölzl, Johansson, & Wennberg, 2014b; Colombelli, Krafft, & Quatraro, 2014).

Such a shift has arguably been due to increasing recognition of the limitations associated with the focus on growth rates, particularly given recent work calling into question the validity of the most commonly used growth measures (Daunfeldt

et al. 2015). Whilst a full discussion of such measures is outwith, the focus of this paper (see Brown et al. 2017 for a concise discussion), the definition and measurement of HGFs is relevant for value creation and cannot be overlooked. This is particularly the case when considering the use of turnover as a growth measure. Although many recent studies have adopted the OECD's definition of HGFs using turnover, few reflect on how and why such changes in turnover fundamentally occur. Rather than acknowledging that any changes in turnover stem from increased (or decreased) *customer purchases* or demand (Satterthwaite & Hamilton, 2017), be it in terms of changes in sales volume or sales value, turnover is treated simply as an abstracted concept where issues such as sales and customers do not feature.

Indeed, very few studies generally acknowledge customers and those that do offer only sporadic and superficial insights. These insights indicate that HGFs are likely to shy away from large consumer markets, preferring instead to develop close relationships with a small number of customers (Brush, Ceru, & Blackburn, 2009; Feindt, Jeffcoate, & Chappell, 2002; Hinton & Hamilton, 2013; Siegel, Siegel, & MacMillan, 1993), predominantly in the business-to-business sphere (Mason & Brown, 2010) rather than business-to-consumer. As a result of favouring such close relationships, these firms are thought to have a keen sense of their customers' needs and desires (Barringer et al., 2005) and to demonstrate strong customer and end user (Mason & Brown, 2010; Parker, Storey, & van Witteloostuijn, 2010) engagement. Interestingly, HGFs are also considered to be customer oriented and, as previously mentioned, focus on strategically creating unique value for their customers (Barringer et al., 2005; Birley & Westhead, 1990; Kim & Mauborgne, 1997; Lindič, Bavdaž, & Kovačič, 2012; Puhakka & Sipola, 2011; Smallbone et al., 1995; Zhang et al., 2008) in a way that differentiates them from other firms. Despite authors noting the importance of value creation as a differentiator of HGFs, none of the studies listed above specifically investigate the issue of value creation. These studies also lack methodological reasoning, clarity, and transparency perhaps due to authors relying on second hand data such as narrative case studies (e.g. Barringer et al., 2005), or due to the complexity of value creation as a construct and its limited use in entrepreneurship research.

Within the marketing literature, however, the concepts of value and value creation have been topics of discussion for decades. As with high growth entrepreneurship, the value literature has also gained momentum over recent years. Value-based and value-focused strategies have become a central theme, not only in marketing but across the wider business literature (Khalifa, 2004; O'Cass & Ngo, 2011), with authors suggesting that a firm's success rests on its ability to provide superior value to their customers (Rintamäki, Kuusela, & Mitronen, 2007; Sirmon et al., 2007). Given the complexity of the value concept, it is little wonder that the value literature also has its share of conceptualisations and definitions (for a concise review, see Khalifa, 2004). Scholars have explored a number of different 'types' of value including shareholder value, supplier value, stakeholder value and customer

value – which some consider to be the source of all other forms of value (Lemon, Rust, & Zeithaml, 2001). Even when looking at customer value specifically, it is important to acknowledge that value can be viewed from the perspective of *exchange value*, measured by the amount of money paid for something, or *customer perceived value*, where value is measured by customer perceptions of benefit and utility (Bowman & Ambrosini, 2000).

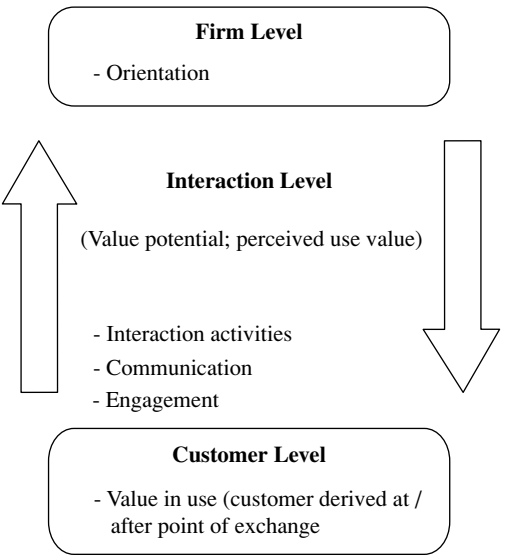
Customer perceived value is a particularly complex construct; the literature contains many divergent views on its conceptualisation. Part of the complexity stems from the fact that customers can form perceptions of value before purchase (pre-use value) (Doyle, 2000; Holbrook, 1999), but also post-purchase though the use of that purchase (value in use) (Payne, Storbacka, & Frow, 2008; Vargo & Akaka, 2009). Whilst these are two unique facets of customer perceived value, they are arguably two equally important parts of the customer value creation process, particularly as value in use is seen to develop directly from pre-use value (Grönroos, 2008). Ultimately, customer perceived value stems from individuals´ unique 'in use' experiences and is thus necessarily phenomenological, subjective, intrinsic, and dynamic (Vargo & Lusch, 2008b) although firms can play a role in influencing this value creation process by affecting a customer's *perceived use value* (e.g. utility, efficiency, status, benefits etc.) through interactions before use (Ballantyne, 2004). This form of value, henceforth referred to as customer perceived value, will be the focus of this paper.

Despite a plethora of studies exploring customer perceived value, there is still little known about the process of customer perceived value creation (Vargo, Maglio, & Akaka, 2008), specifically when the process begins and ends (Grönroos, 2011), what the process includes, and what a firm's role is in this process. From a firm growth perspective, we also do not understand how value creation links with changes in firm performance. The 'interaction concept' stemming from the so-called Nordic School[2] provides a useful way of conceptualising value, whereby the interactions or 'encounter processes' (Payne et al., 2008) between firms and their customers are what facilitate value creation. Each individual interaction facilitates the sharing of information, fosters joint decision-making, and encourages trust (Batt & Purchase, 2004), allowing for a dialogical process whereby customers are able to create meaning and value for themselves. Thus, it is not the role of the firm to attempt to create value *for* a customer, but rather to work with a customer to create potential value by incorporating a customer's own unique value creation activities into the firm's own system and activities (Ballantyne & Varey, 2006; Normann & Ramirez, 1993; Wikström, 1996).

[2] The 'interaction concept' stems from the work of the so-called Nordic School, which is part of the service and relationship marketing literature (e.g. Grönroos, 1982; Gummesson, 1997). This puts the focus of value creating activities on the interactions between firms and their customers rather than at simply firm or customer level. The rationale for this is that it allows for a dialogical process between a firm and its customers that, in turn, enables the creation of meaning for customers and, therefore, potential value (Ballantyne, 2004).

There are many activities that function on the 'interaction level', bearing in mind that some customers will choose to engage with firms more deeply than others (Vargo & Lusch, 2008a). Deeper engagement results in a greater potential for value creation (Brodie, Hollebeek, Juric, & Ilic, 2011). These can be conceptualised as falling into three main categories: *general interaction activities* such as 'co-production' activities focused on the joint creation of products/services with customers (Blazevic & Lievens, 2008; Ertimur & Venkatesh, 2010) and broader 'co-creation' activities such as the provision of customisable 'solutions' (Davies, 2004; Tuli, Kohli, & Bharadwaj, 2007); *communication*, including two-way vs. one-way communication with customers (Kumar et al., 2010), method and frequency of communication (Agnihotri, Dingus, Hu, & Krush, 2016; Finne & Grönroos, 2017); and *customer engagement*, where a firm's behaviour encourages a customer relationship to develop beyond transactions (Brodie et al., 2011; van Doorn et al., 2010) to ultimately encourage repeat customer purchase and customer referral (Kumar et al., 2010). These elements constitute this paper's conceptual framework (see Figure 1 below).

Figure 1.
Activities Influencing Customer Perceived Value



Source: Author.

Reviewing the high growth entrepreneurship literature, some of these 'value creating' activities at the interaction level mirror observations of HGF activities and behaviours. For example, HGFs have been noted to regularly talk to their customers to gain a better understanding of their needs (Barringer et al., 2005) and

to develop new, innovative and highly differentiated offerings (Hinton & Hamilton, 2013). They are also considered to be focused on customer service (Kirkwood, 2009), developing strong relationships with their customers (Brush et al., 2009). As discussed earlier, these observations lack empirical backing, which is an important gap in knowledge that this paper attempts to fill.

METHODOLODY

Research Approach

Given the exploratory nature of this paper and its focus on value creation activities within individual firms, a qualitative approach drawing on semi-structured interviews was considered to be the most suitable way to collect the detailed and contextual data needed (King, 2004) to address the core research question.

To avoid 'success bias' (Mohr & Garnsey, 2011; Shane, 2009), which is prevalent in much of the current work on HGFs, the study examined a comparative cohort of non-HGFs in order to determine whether value creation activity is in fact a differentiator between high growth firms and their counterparts. Such comparative cohort studies are limited within the HGF literature (Barringer et al., 2005; Boston & Boston, 2007; Brown & Mawson, 2016; Chandler et al., 2014; Coad, Cowling, & Siepel, 2017; Moreno & Casillas, 2007), yet are arguably an important methodology for exploring HGFs as a discrete group.

Sampling, Data Collection, and Data Analysis

In line with other recent work on HGFs (e.g., Brown & Mawson, 2016; Coad et al., 2017; Du & Temouri, 2015; Kidney, Harney, & O'Gorman, 2017; Ng & Hamilton, 2016), firms were identified using the Financial Analysis Made Easy (FAME) commercial database, which contains financial information submitted to Companies House. Scotland was selected as the location for this study given sustained numbers of HGFs and a policy environment promoting entrepreneurship (Lee, 2014; Mason & Brown, 2013). HGFs were purposively identified (Corbin & Strauss, 1990) and were required to meet the OECD turnover definition for the three-year period between 2006-2009. From this population, a random sample of HGFs (50 companies) was selected. For the comparative sample of non-HGFs, purposive sampling was also used. Given that HGFs must have more than ten employees, the population of non-HGFs with more than this number was identified. Those firms that had seen modest turnover growth (1-10% between 2006-2009) were identified as the target non-HGF population. This purposive sampling was required in order to identify a cohort of slower-growing firms that would best contrast with the HGF cohort – firms that were stable or achieving modest growth rather than those in decline. From this population, a random sample of fifty firms was selected and contacted for interview. From the two HGF and non-HGF samples,

22 interviews were arranged and conducted with Managing Directors – eleven with HGFs and ten with non-HGFs.

Depth qualitative interviews were conducted face-to-face, and the discussion was focused on issues relating to customer interaction. At no time were participant firms identified as HGFs or non-HGFs. The average length of the interviews was 68 minutes. Interviews were recorded and transcribed immediately after completion, and companies were allocated a unique identifier to ensure anonymity.

As advocated by several authors (including Graebner, 2004), all the qualitative material collected was subjected to both 'within-case' and 'cross-case' analysis for each of the firms (Miles & Huberman, 1994). Thus, the qualitative data analysis undertaken focused on enabling the richness of the data to be fully explored and to "let the data speak for itself" (Easterby-Smith, Thorpe, & Lowe, 2006, p. 119). Interview transcripts and notes were first examined for key themes and patterns. The data was then coded into a number of *a priori* categories, with new categories created for all emergent issues (Graebner, 2009).

FINDINGS

The qualitative data gathered during the interviews provided some very important insight into the nature of value-creating interactions within HGFs. It was possible to discover how HGFs (and non-HGFs) communicated and engaged with their customers (their method, frequency, and depth of communication) and the types of interactions they had with customers. These are now discussed in detail.

Customer Focused Orientation

Whilst not strictly related to activities on the 'interaction level', during the interviews, it became clear that firm orientation played a particularly important role when it came to influencing interaction activities. In general, HGFs tended to espouse a much more customer focused orientation than their non-HGFs counterparts, making it very clear that they consider their customers to be central to all firm level activities.

> "Our customers are everything to us. And we will do anything in our power to build long-term relationships with them." HGF_7

> "Of course our customers are important, but we have to remember that they are one part of everything we do here." nHGF_8

Whilst the quotations above reflect HGFs and non-HGFs' views, respectively, it is not fair to say that the non-HGFs interviewed were not customer focused. They did appear to be considerably less so, however, when being directly compared with the HGF sample. The non-HGFs clearly recognised the importance of their customers, had an understanding of customer needs, and integrated customer insight back into

the company; however, they did not display the same commitment to putting customers at the heart of their business as the HGF cohort.

This lack of 'customer focused orientation' may explain why non-HGFs did not demonstrate the same levels of proactiveness, responsibility, and flexibility as the HGF cohort – elements considered to be integral to meeting and exceeding customer expectations (Parker et al. 2010; Sawhney, 2006). A number of non-HGFs (6 out of 11) noted that they strategically chose to focus most of their attention on their biggest clients; thus, smaller customers did not receive the same amount of focus and attention.

> "Well, we've only got so much time, so we focus based on the size of the account. If the account is coming up towards the size of [a] £1m account then they get more of our time than if it's a tiny little account £25,000/£30,000 - then we might only go out to speak with them once a year." nHGF_9

A very different picture emerged for the HGFs: every single one demonstrated significant customer-focus, regardless of whether these were new or existing customers and large or small accounts. The HGFs interviewed exhibited a strong sense of customer focus. For many, customers were not considered to be external purchasers of products or services, but "*really part of this company*" and "*part of the family*". Underlying this commitment to customers was an articulated organisational focus on trust and relationship-building. Interestingly, these issues were never specifically identified by non-HGFs although they were probed for during interviews. HGFs, however, were keen to stress the importance that trust played not only in terms of reputation generally, but also regarding relationship-building with customers. This reflects observations made in other work that looks at HGFs (Reuber & Fischer, 2005).

> "[Our sales] are very much relationship sales; it's a business sale but it's a relationship sale. It's all about trust and long term outcomes that benefit us and our customers." HGF_3

As HGF_5 further elaborated:

> "Once you start actually working with a customer and get to understand where they are [and] where you're going together, something magical happens. It's as though they become part of you - and that's where you really want to get to."

Customer Communication and Engagement

In line with customer focus issues, the HGF and non-HGF cohorts differed in terms of their communications and engagement with customers. HGFs were more likely to see a greater percentage of their turnover growth come from repeat customers than their non-high growth counterparts who tended to see a higher percentage of turnover growth coming from new customers. As such, HGFs tended to

prioritise communication with current customers whilst non-HGFs largely sought to communicate with new customers.

The HGF cohort also tended to focus on 'two-way' communications drawing on regular telephone, email, and face-to-face communications in addition to other wider 'social' media usage (predominantly Twitter, blogs, YouTube). As HGF_10 noted: *"we try to communicate with our customers regularly through a number of different channels - depending on that customer's preferences of course."* These communications were often conducted in the context of a formalised 'Account Management' system, particularly for bigger clients and those requiring a greater amount of support.

> "Each of our customers has an Account Manager. We have to be really close to our customers - we need to know what they are going to want at least two years before they know they want it. We need to have foresight. It's being able to say right, here's what they are going to want and here's how we are going to plan for - and deliver - that." HGF_2

It was often in the context of such an Account Management system that HGFs sought to develop a sense of "*extraordinary experience*" for their customers, drawing on the relational understanding fostered by account managers to address unique customer needs in depth. This, in turn, allowed the companies to better understand their customers' changing wants and needs and to react accordingly; they often pre-empted customer requests and mitigated the potential for any problems.

> "We have a customer who has this specific bit of kit for the oil and gas sector. We had been working with him for a few years when he told us wanted to do business in China with [Chinese petroleum company], but our service wasn't available over there yet for them to use and could we do something about that. What else do you do but jump on a plane and spend three months in China and get the service up and running there!" HGF_1

A different picture emerged among the non-HGFs interviewed. These companies tended to prefer more reactive and one-way communications such as cold calling, advertisements, newsletters, and promotions. The rationale for these activities often stemmed from a belief that if prospective customers were more aware of the company and what it offered they would be inclined to purchase, which reflected their focus on new customers for turnover growth.

> "[W]hat we also do is we try and get people - when they are buying on our website - to click onto our Facebook page and join us as a fan there. That means that you've got them and then you can post on a promotion, like 'win a free wee [product]'." nHGF_6

> "We just launched a specific website this week for a new product. [Name], our marketing/finance girl, sent an e-mail out - and will continue sending e-mails out - to every single person that has ever had any interest or involvement

> in [product category] that we have been in contact with. It's not a heavy sell, it's just 'here's the website - have a look'." nHGF_4

A number of these non-HGF companies (6 out of 10) also relied heavily on social media, mostly Facebook, as their primary method of customer engagement. However, their use of social media was less about starting a two-way dialogue with existing and potential customers and more about capturing individuals' attention and leading them to the company website either directly or through promotional activities. Once they had been directed to the main website, communication ceased and customers were largely left without follow-up interactions. Two-way communications with customers were seldom acknowledged by non-HGFs (1 out of 10 firms), and, when probed during interviews, the issue was glossed over by respondents as *"too expensive"* or *"not something that we do"* or *"too time consuming"*.

This issue of time was another important difference between HGFs and non-HGFs, specifically the frequency of communication and engagement activities undertaken by the two groups. Within the HGF cohort, customer communication took place on a regular (and often daily) basis. HGF_6 noted that: *"it's constant communication. Some clients are further ahead than others, of course, but we're talking at least a couple of times a week, up to a couple of times a day."* The rationale behind such frequent communication was that these firms sought to build very close and long-term relationships with their customers, rather than have more transactional relationships. To do so, HGFs were quick to articulate the importance of having communications on a "*business*" or "*product*" level, but also on a "*personal*" level.

> "If I don't know about [a client] and what he's like - how he thinks, how he works, what makes him tick - how can we expect to go and help offer to help meet his and his business' needs?" HGF_10

This level of frequent customer engagement and communication was not as prevalent amongst the non-HGFs. In line with their preference to undertake more one-way communication activities, the non-HGFs interviewed were more sporadic in their approach, with communications occurring intermittently and not as part of a larger engagement plan or strategy. nHGF_3 was particularly candid and noted: *"we do our best, but maybe we're not as good at this [regular communication with customers] as we ought to be."* A number of the non-HGFs relied on quarterly email newsletters for communication with customers, but many noted that "*we don't always get it out*" or "*the time-table isn't set in stone - sometimes it slips by a couple of months or so*". Generally, the sentiment from non-HGFs was that they would prefer to develop and disseminate any communications on their own terms and in their own time rather than taking a more customer-led approach.

> "I don't want to go out bothering people… but we do have very regular communication with our major clients – they call or email [us] every few months or so." nHGF_2

As noted in the literature, the methods and frequency of communication adopted by firms have a direct impact on the depth of engagement that a firm will be able to develop with its customers (Brodie et al., 2011), and, in turn, on perceived value creation. For HGFs, deep customer engagement was considered to be a core organisational focus, with many firms displaying a clear 'customer orientation'. Such customer engagement was often facilitated by having what one firm identified as "*multiple communication interfaces*" between the firm and each customer. This was further elaborated upon by HGF_4:

> "It's a deliberate policy in that we open the doors at all levels between us and our customers. So, for example, we have our planners talking to their planners, we have our R&E [Review & Evaluation] people talking to their R&E people, QA [Quality Assurance] people talking to QA people and managers talking to managers. They will all be talking directly and that is something we have evolved over the years. Again, it's very much a realisation that the more interconnected we become, the better it is for them and then of course the better it is for us."

Through investing in customer engagement, HGFs appeared to not only be able to attract new customers and satisfy short-term customer needs, but also able to build long-term relationships that facilitated repeat purchases from existing customers. When looking beyond a transactional approach and focusing on customers' unique motivational drivers, the HGFs interviewed were actively striving to engage as deeply as possible and to provide as much perceived value as possible.

> "We work hard at engaging with clients. We try and factor in some basic thinking around, even at an individual level, what type of person is best to be the main point of contact, as we have got different personality types here. Or how might a client want to be communicated with? Some clients are very sociable, so maybe it's going for a beer or a coffee, and some of them want to keep it very business-like so we try and adapt accordingly. It's all about them, after all!" HGF_11

Perhaps unsurprisingly, given their more reactive and intermittent communications with customers, the interviewed non-HGFs appeared less likely to be undertaking deeper customer engagement. Whilst many factors contributed to this, including a perceived lack of time and perceived cost, there seemed to be a genuine belief within these companies that customer engagement was a *"secondary issue"* or *"not core"* to the business. Perhaps this is why many non-HGFs were less prepared than HGFs to devote the time, money, and personnel necessary to this process.

Interactions with Customers

As discussed earlier, it is through interactions with customers that firms are ultimately able to influence customer perceived value creation (Ballantyne, 2004).

Whilst communications and engagement with customers are important elements of customer-firm interaction, interactions can also include 'co-production' and 'co-creation' activities (Blazevic & Lievens, 2008; Ertimur & Venkatesh 2010). When probed about the nature of their offerings, both the HGF and non-HGF cohorts were selling a combination of physical products and intangible services. HGFs were, however, more likely than non-HGFs to be seeing sales growth from more bespoke offerings.

In line with their customer focus and customer engagement, HGFs were actively tailoring offerings to their customers' specific needs, as well as engaging with customers to undertake product/service co-production. These companies noted a number of ways in which they engaged in co-production, including working with customers to redevelop and customise existing products; involving customers in initial product concept development and testing; and working with customers throughout the entire new product development cycle to develop specific, highly customised offerings. As HGF_2, a potato producer, explained:

> "Some people might say that 'a potato is a potato', but that's not really the case. We work closely with our customers to develop potato flavours and textures to suit changing consumer tastes, using consumer preference testing as well as sensory profiling. If our customers are looking for a more 'buttery' potato, we will work with them to get the right amount of butter flavour and the right amount of dairy flavour and the right amount of flour-y-ness for that brand of potato and so on."

The number, type, and frequency of co-creation/co-production interactions varied across HGFs: they were largely dependent upon the type of offering and the individual customers' preferred level of involvement. Regardless of the approach chosen, the rationale was consistent among firms: to provide as much value as possible to their customers. Many of the HGFs (8 out of 11) articulated that their firm existed to serve customers, noting that they felt "*subservient*" to or "*wholly reliant"* on their customers and that it was their responsibility "*do whatever it is that's best for our clients*". For many HGFs, this required the development of customised and integrated business solutions for their customers. In fact, the majority of HGFs (9 out of 11) identified themselves as *solutions providers*, articulating that they were "*solutions driven*" and "*selling a solution*" that was designed with clients to meet their own individual needs.

There was a lot less evidence of such interactions within the non-HGFs; discussions of co-creation and co-production were largely absent during interviews. Whilst these firms were developing their own new products, re-developing existing products and articulating a focus on innovation, the interactions with customers that underpin co-creation or co-production activities were notably lacking. For example, whilst nHGF_5 had its own product development programme, it identified that new products were developed "*based on what our customers tell us they need and what we think might be useful to them, which we then develop, make and*

take to them as a marketable product." Customers were largely attributed to have some initial input, but were seldom involved during the rest of the development, design and manufacturing process.

> "We're not Apple with thousands of people who come in in the morning and can spend all day trying to innovate. And the customer doesn't always know what he wants, so we've got to show him what he might want. We prefer to lead on product development and then sell it." nHGF_10

Although several non-HGFs discussed tailoring items to meet customer needs (3 out of 10), when probed further it was apparent that this was more to do with making minor substitutions and changes, rather than actively developing products through an iterative and two-way process. Interestingly, the non-HGFs interviewed genuinely believed they were interacting with their customers to provide *"added value"*. However, when in direct comparison with the cohort of HGFs, it was clear that this interaction was more superficial.

DISCUSSION

The findings presented provide some important insights into the nature of activities facilitating the creation of customer perceived value. As noted earlier, however, there is significant complexity in the perceived value creation construct, which makes it very difficult to empirically examine. This explains why, despite observations in the literature that value creation is a differentiator for HGFs (Barringer et al., 2005; Kim & Mauborgne, 1997; Smallbone et al., 1995; Zhang et al., 2008), there has been a lack of empirical evidence to confirm this relationship. The findings reported, whilst by no means conclusive, empirically support the assertion that the creation of customer perceived value is a differentiating characteristic of HGFs and help us to better understand how these firms differ in terms of their capability (and likelihood) to facilitate the creation of perceived value by their customers.

A firm's orientation, or the beliefs and values that underpin its actions and decisions, is widely recognised as having an effect on firm performance (Goll, Sambharya, & Tucci, 2001) and is also increasingly recognised to be an important part of influencing customer perceived value creation (O'Cass & Ngo, 2011), particularly when a firm is focused on its customers. Arguably those firms with an articulated and enshrined desire to create and maintain value for customers have a stronger likelihood of positively influencing value creation. As discussed, HGFs exhibited high levels of customer focus, as well as a proactive approach towards satisfying - and exceeding - the expectations of each and every one of their customers. This was in contrast to the non-HGF cohort, which did not demonstrate the same level of customer focus. Even in terms of competitive priorities, the HGFs prioritised quality and service to customers, rather than price or product leadership (Sawhney, 2006), confirming previous observations in the literature that HGFs

exhibit a customer-centric ideology and orientation (Mason & Brown, 2010; Parker et al., 2010).

Such customer focus was also reflected in how HGFs communicated and engaged with their customers, differing from their non-HGF counterparts in a number of areas (see Table 1), including the method and frequency of communication with customers, as well as the depth of that engagement.

Table 1.
Differences in Interaction Activities and Potential for Influencing Customer Perceived Value.

	HGFs	**Non-HGFs**
Customer orientation	High	Middle to low
Target customer group	Repeat customers	New customers
Nature of engagement	Proactive; two-way engagement	Reactive; one-way engagement
Interaction activities	Social media; face to face; account management; co-creation; solutions building	Cold-calling; newsletters, promotions; social media; face to face
Intended customer response	Enthusiasm, interaction, extraordinary experience	Awareness, enthusiasm
Influence on perceived value	High	Middle to low

Source: Author.

In general, the HGFs interviewed were engaging deeply with their customers and tended to focus on more proactive two-way engagement activities (e.g. account management systems) that had a high impact on customer perceived value. Given the customer-specific nature of these engagement activities, however, they required more firm resources (notably time) to effectively operate than the more reactive activities (e.g. newsletters or promotions) undertaken by the non-HGFs. Despite the greater resources needed to undertake such a depth of engagement, the HGFs interviewed clearly articulated their organisational focus on facilitating customer interactions with their ultimate goal being to create a sense of *extraordinary experience* for their customers.

These HGFs seemed to subscribe to the concept found in the value literature that firm-customer interactions should be a "process of parties doing things for and with each other, rather than trading units of output, tangible or intangible" (Vargo & Lusch, 2008b, p. 29). This idea was reflected in how they interacted with customers to influence value creation, for example through co-production and customised solutions (Davies, 2004; Tuli et al., 2007), both of which focus more on

the process of requirements definition, customisation, and integration than they do on simple transactions. Interestingly, many of the HGFs identified and articulated (unprompted) how they helped to create value for customers and how this contributed to their firms' growth and financial performance. This supports assertions in the literature that a firm's success rests on its ability to provide maintained superior value to their customers (Rintamäki et al., 2007; Sirmon et al., 2007)

CONCLUSIONS

Returning to the original question underpinning this research, this paper fills a gap in the high-growth entrepreneurship literature by empirically exploring the relationship between HGFs and customer perceived value creation. We can now say with greater certainty that value creation does appear to be a differentiator of HGFs (Barringer et al., 2005; Birley and Westhead, 1990; Kim and Mauborgne, 1997; Smallbone et al., 1995; Zhang et al., 2008).

Whilst this paper makes an important contribution to the literature, it is not without its limitations. In terms of methodology, this research adopted a cross-sectional approach which scholars have noted can be problematic when trying to examine HGFs (Brown & Mawson, 2013; Lee, 2014). It would have been beneficial to employ a longitudinal approach to collect data on firm-customer interactions and firm performance at more regular intervals over a longer period of time. This would have allowed for the link between value creation activities and firm performance to be more closely scrutinised to see if there is in fact a positive relationship between the elements discussed in this study and changes in firm turnover. Drawing on two small cohorts of firms from a single geography means that the findings reported are context-specific and indicative, rather than widely generalizable to other HGFs in different regions. There is very much a need for further quantitative studies to corroborate this paper's findings for a wider range of HGFs, ideally across different geographies.

Additionally, it was very difficult to decipher when value creation activities and behaviours were adopted/implemented. This is linked to the perennial problem of identifying HGFs *ex ante* (Coad et al. 2017). HGFs are, by necessity, identified retrospectively, so it was not possible to determine whether the activities observed predated the period of rapid growth, or resulted during/from that growth period. Further research on this issue would make an important contribution to the literature.

Finally, this study applied the OECD turnover definition of a HGF. As noted, there has been substantial debate over definitional issues (Daunfeldt et al., 2015); scholars have queried the current employment and turnover metrics. In relation to value creation, it is important to better understand the link between customer value, turnover, and profitability. As Vinnel and Hamilton (1999) observe, high growth needs to be profitable in order to be sustainable. Further research is needed to explore

whether customers are merely driving sales growth or ensuring profitability (and perhaps longevity) for firms.

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ARTÍCULO

TOOLS FOR CAUSAL INFERENCE FROM CROSS-SECTIONAL INNOVATION SURVEYS WITH CONTINUOUS OR DISCRETE VARIABLES: THEORY AND APPLICATIONS

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We are grateful to Sara Amoroso, Eric Bartelsman, Marco Capasso, Sebastiano Cattaruzzo, Francesca Chiaromonte, Sergio Chión, Giovanni Dosi, Ove Granstrand, Marco Grazzi, Alex Kleibrink, Alessio Moneta, Gabriel Natividad, Jens Sorvik, Mercedes Teruel, and Antonio Vezzani as well as seminar participants at CENTRUM Católica Graduate Business School (Lima, Peru) and participants at the Peru Economics Associations congress. We are also grateful to the Peru Economics Association congress 2017, the Sant'Anna School of Advanced Studies (Pisa), Universidad de Piura (Lima, Peru), Universitat Rovira I Virgili (Reus, Spain), the University of California Berkeley, and the two anonymous reviewers for their many helpful comments. This paper is heavily based on a report for the European Commission (Janzing, 2016). Some software code in R (which also requires some Matlab routines) is available from the authors upon request. The usual caveats apply.

Suggested citation: Coad, A., Janzing, D., & Nightingale, P. (2018). Tools for causal inference from cross-sectional innovation surveys with continuous or discrete variables: Theory and applications. *Cuadernos de Economía, 37*(75), 779-808. doi: 10.15446/cuad.econ.v37n75.69832

Este artículo fue recibido el 16 de enero de 2018, ajustado el 21 de febrero de 2018, y su publicación aprobada el 09 de marzo de 2018.

Coad, A., Janzing, D., & Nightingale, P. (2018). Tools for causal inference from cross-sectional innovation surveys with continuous or discrete variables: Theory and applications. *Cuadernos de Economía*, *37*(75), 779-808.

This paper presents a new statistical toolkit by applying three techniques for data-driven causal inference from the machine learning community that are little-known among economists and innovation scholars: a conditional independence-based approach, additive noise models, and non-algorithmic inference by hand. We include three applications to CIS data to investigate public funding schemes for R&D investment, information sources for innovation, and innovation expenditures and firm growth. Preliminary results provide causal interpretations of some previously-observed correlations. Our statistical 'toolkit' could be a useful complement to existing techniques.

Keywords: Causal inference, innovation surveys, machine learning, additive noise models, directed acyclic graphs.
JEL: O30, C21.

Coad, A., Janzing, D., & Nightingale, P. (2018). Herramientas para la inferencia causal de encuestas de innovación de corte transversal con variables continuas o discretas: Teoría y aplicaciones. *Cuadernos de Economía*, *37*(75), 779-808.

Este artículo presenta un nuevo conjunto de herramientas estadísticas al aplicar tres técnicas de inferencia causal basada en datos tomadas de la comunidad del aprendizaje automático (*maching learning*) y que son poco conocidas entre los economistas y los académicos de la innovación: un enfoque condicional basado en la independencia, modelos de ruido aditivo e inferencia no algorítmica a mano. Incluimos tres aplicaciones a los datos de la CIS —la encuesta de la comunidad sobre la innovación— para investigar los modelos de financiación pública para inversión en investigación y desarrollo, fuentes de información para la innovación, y gastos de innovación y crecimiento empresarial. Los resultados preliminares proporcionan interpretaciones causales de algunas correlaciones observadas previamente. Nuestro conjunto de herramientas estadísticas podría ser un complemento útil a las técnicas existentes.

Palabras clave: inferencia causal, encuestas de innovación, aprendizaje automático (*machine learning*), modelos de ruido aditivo, grafos acíclicos dirigidos.
JEL: O30, C21.

Coad, A., Janzing, D., & Nightingale, P. (2018). Outils pour l'inférence causale d'enquêtes d'innovation de bilan transversal avec des variables continues ou discrètes : Théorie et applications. *Cuadernos de Economía*, *37*(75), 779-808.

Cet article présente un nouvel ensemble d'outils statistiques en appliquant trois techniques d'inférence causale basée sur des données prises de la communauté de l'apprentissage automatique (*maching learning*) et qui sont peu connues chez les économistes et les spécialistes de l'innovation : une approche conditionnelle basée sur l'indépendance, des modèles de bruit additif et inférence non algorythmique

manuelle. Nous incluons trois applications aux données de la CIS –l'enquête de la communauté sur l'innovation- pour étudier les modèles de financement public pour l'investissement en recherche et développement, sources d'information pour l'innovation, et dépenses d'innovation et de croissance entrepreneuriale. Les résultats préliminaires fournissent des interprétations causales de certaines corrélations observées antérieurement. Notre ensemble d'outils statistiques pourrait être un complément utile aux techniques existantes.

Mots-clefs: inférence causale, enquêtes d'innovation, apprentissage automatique (*machine learning*), modèles de bruit additif, graphes acycliques dirigés.
JEL: O30, C21.

Coad, A., Janzing, D., & Nightingale, P. (2018). Ferramentas para a inferência causal de pesquisas de inovação de corte transversal com variáveis contínuas ou discretas: teoria e aplicações. *Cuadernos de Economía*, *37*(75), 779-808.

Este artigo apresenta um novo conjunto de ferramentas estatísticas aplicando três técnicas de inferência causal baseadas em dados extraídos da comunidade de aprendizado automático (*maching learning*) e que são pouco conhecidas entre economistas e estudiosos da inovação: uma abordagem condicional baseada na independência, modelos aditivos de ruído e inferência não algorítmica à mão. Incluímos três aplicativos para os dados da CIS — a pesquisa da comunidade sobre inovação — para investigar os modelos de financiamento público para investimento em pesquisa e desenvolvimento, fontes de informação para inovação e gastos com inovação e crescimento de negócios. Os resultados preliminares fornecem interpretações causais de algumas correlações observadas anteriormente. Nosso conjunto de ferramentas estatísticas pode ser um complemento útil para as técnicas existentes.

Palavras-chave: inferência causal, pesquisas sobre inovação, aprendizado automático (*machine learning*), modelos de ruído aditivo, gráficos acíclicos dirigidos.

INTRODUCTION

The design of effective policy recommendations requires an understanding of not only the associations between key variables but also the causal relations governing the interactions of these variables (Spirtes, Glymour, & Scheines, 2000; Pearl, 2009; Peters, Janzing, & Schölkopf, 2017). However, a long-standing problem for innovation scholars is obtaining causal estimates from observational (i.e. non-experimental) datasets (Nichols, 2007; Cassiman & Veugelers, 2002; Heckman, 2010). For a long time, causal inference from cross-sectional surveys has been considered impossible. Nevertheless, advances in statistics and analysis of causality, combined with 'big data' and increases in computational power, have led to dramatic improvements in the ability of researchers to obtain causal estimates from observational datasets.

Hal Varian, Chief Economist at Google and Emeritus Professor at the University of California, Berkeley, commented on the value of machine learning techniques for econometricians:

> My standard advice to graduate students these days is go to the computer science department and take a class in machine learning. There have been very fruitful collaborations between computer scientists and statisticians in the last decade or so, and I expect collaborations between computer scientists and econometricians will also be productive in the future. Hal Varian (2014, p.3).

This paper seeks to transfer knowledge from computer science and machine learning communities into the economics of innovation and firm growth, by offering an accessible introduction to techniques for data-driven causal inference, as well as three applications to innovation survey datasets that are expected to have several implications for innovation policy.

The contribution of this paper is to introduce a variety of techniques (including very recent approaches) for causal inference to the toolbox of econometricians and innovation scholars: a conditional independence-based approach; additive noise models; and non-algorithmic inference by hand. These statistical tools are data-driven, rather than theory-driven, and can be useful alternatives to obtain causal estimates from observational data (i.e. instrumental variables techniques and regression discontinuity design). While several papers have previously introduced the conditional independence-based approach (Tool 1) in economic contexts such as monetary policy, macroeconomic SVAR (Structural Vector Autoregression) models, and corn price dynamics (e.g. Swanson & Granger, 1997; Moneta, 2008; Xu, 2017; see also Kwon & Bessler, 2011 for a survey), nevertheless the conditional independence-based approach has little been used in the context of the economics of innovation. Tool 2, and also Tool 3 (except for LiNGAM: see Moneta, Entner, Hoyer, & Coad, 2013 and Lanne, Meitz, & Saikkonen, 2017), are new to the field of economics. A further contribution is that these new techniques are applied to three con-

texts in the economics of innovation (i.e. funding for innovation, information sources for innovation, and innovation expenditures and firm growth) to obtain several interesting and policy-relevant results.

While most analyses of innovation datasets focus on reporting the statistical associations found in observational data, policy makers need causal evidence in order to understand if their interventions in a complex system of inter-related variables will have the expected outcomes. This paper, therefore, seeks to elucidate the causal relations between innovation variables using recent methodological advances in machine learning. While two recent survey papers in the Journal of Economic Perspectives have highlighted how machine learning techniques can provide interesting results regarding statistical associations (e.g. classification problems, regression trees, random forests, penalized regression, LASSO; see Varian, 2014 and Mullainathan & Spiess, 2017), we show how machine learning techniques offer interesting opportunities for causal inference.[1]

Section 2 presents the three tools, and Section 3 describes our CIS dataset. Section 4 contains the three empirical contexts: funding for innovation, information sources for innovation, and innovation expenditures and firm growth. Section 5 concludes.

METHODOLOGY

The basic assumption relating statistics and causality is Reichenbach's principle (Reichenbach, 1956), which states that every statistical dependence between two observed random variables X and Y indicate at least one of the following three alternatives is true: 1) X influences Y , 2) there is a common cause Z influencing X and Y, or, 3) Y influences X. In the second case, Reichenbach postulated that X and Y are conditionally independent, given Z, i.e., their probability densities satisfy the equation:

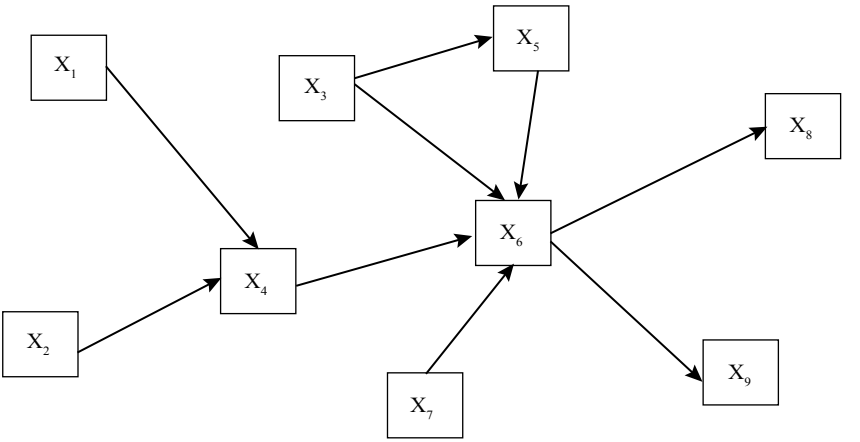
$$p(x, y|z) = p(x|z)p(y|z) \quad (1)$$

for all x, y, z. Henceforth, we will denote this by X independent of Y, given Z.

The fact that all three cases can also occur together is an additional obstacle for causal inference. For this study, we will mostly assume that only one of the cases occurs and try to distinguish between them, subject to this assumption. We are aware of the fact that this oversimplifies many real-life situations. However, even if the cases interfere, one of the three types of causal links may be more significant than the others. It is also more valuable for practical purposes to focus on the main causal relations. After all, statements such as "every variable influences every other variable" are not especially helpful as guidance for future policies.

[1] George, Haas, and Pentland (2014) emphasize that big data techniques must move from investigating correlations to investigating causal effects.

Figure 1.
Directed Acyclic Graph.



Source: the authors.

Our causal analysis involves the analysis of Directed Acyclic Graphs (or DAGs, see Figure 1). A graphical approach is useful for depicting causal relations between variables (Pearl, 2009). Arrows denote the direction of causality, and we subscribe to a "manipulation view" of causality (Kwon & Bessler, 2011, p.87) according to the (highly hypothetical) scenario whereby an intervention on one variable has an effect on another, while the remaining variables are kept at a fixed value. If we take the example of x_6 in Figure 1, then its 'children' are x_8 and x_9 while its 'parents' are x_3, x_4, x_5, and x_7. x_1 and x_2 have an indirect causal effect on x_6, operating via x_4, but if we control for x_4, then $[x_1, x_2]$ and x_6 are independent: i.e. $p(x_6|x_4, x_1, x_2) = p(x_6|x_4)$. The property that each variable is independent of its non-descendants – conditional on its parents – is known as the causal Markov condition (Spirtes, Glymour, & Scheines, 2000; Pearl, 2009). This condition implies that indirect (distant) causes become irrelevant when the direct (proximate) causes are known.

The density of the joint distribution $p(x_1, x_4, x_6)$, if it exists, can therefore be represented in equation form and factorized as follows:

$$p(x_1, x_4, x_6) = p(x_1).p(x_4|x_1).p(x_6|x_4) \quad (2)$$

Another important assumption is known as "faithfulness", which allows us to infer dependences from the graph structure. The faithfulness assumption states that only those conditional independences occur that are implied by the graph structure. This implies, for instance, that two variables with a common cause will not be rendered statistically independent by structural parameters that – by chance, perhaps – are fine-tuned to exactly cancel each other out. This is conceptually similar to

the assumption that one object does not perfectly conceal a second object directly behind it that is eclipsed from the line of sight of a viewer located at a specific viewpoint (Pearl, 2009, p.48). In terms of Figure 1, faithfulness requires that the direct effect of x_3 on x_1 is not calibrated to be perfectly cancelled out by the indirect effect of x_3 on x_1 operating via x_5.

In keeping with the DAG perspective on causality, we use an arrow to denote a 'direct' causal influence, but the reader should keep in mind that the distinction between direct and indirect is only meant relative to the set of variables under consideration: 'direct' means that the influence is not mediated by any of the other variables in the DAG. Here we assume that an absolute distinction between 'direct' and 'indirect' influence is meaningless. This perspective is motivated by a physical picture of causality, according to which variables may refer to measurements in space and time: if X_i and X_j are variables measured at different locations, then every influence of X_i on X_j requires a physical signal propagating through space. Thus, we can replace the arrow $X_i \rightarrow X_j$ with an arbitrarily long chain of intermediate variables that refer to measurements along the way as the signal propagates.

Tool 1: Conditional Independence-based approach.

Unconditional independences

Insights into the causal relations between variables can be obtained by examining patterns of unconditional and conditional dependences between variables. For example, although correlation does not equal causation, no causation can be taken to imply no correlation (Kwon & Bessler, 2011, p.90), as implied by Reichenbach's principle.

Bryant, Bessler, and Haigh, (2009) and Kwon and Bessler (2011) show how the use of a third variable C can elucidate the causal relations between variables A and B by using three unconditional independences. Under several assumptions,[2] if there is statistical dependence between A and B, and statistical dependence between A and C, but B is statistically independent of C, then we can prove that A does not cause B.

If X and Y attain one-dimensional numeric values (regardless of whether they are continuous or discrete), they are independent if they are not causally related and thus uncorrelated: $\mathrm{corr}(X, Y) = 0$. In principle, dependences could be only of higher order, i.e., X and Y could be dependent without being correlated, if there is non-linear dependence such as $X^2 + Y^2 = C$. We therefore also use a type of independence test that is able to detect higher-order dependences, namely the

[2] Bryant, Bessler, and Haigh, (2009) assume that Reichenbach's principle of common cause holds true. They assume causal faithfulness (i.e. two variables that share a common cause will not appear to be statistically independent by structural parameters that are 'fine-tuned' so as to precisely cancel each other out). They also assume that there are no causal cycles (such as $A \rightarrow B \rightarrow C \rightarrow A$); however, they do not need to assume that all causally relevant variables are observed.

Hilbert Schmidt Independence Criterion (HSIC) by Gretton, Bousquet, Smola, and Schölkopf (2005) and Gretton, Herbrich, Smola, Bousquet, and Schölkopf (2005). HSIC thus measures dependence of random variables, such as a correlation coefficient, with the difference being that it accounts also for non-linear dependences.

Conditional independences

For multi-variate Gaussian distributions,[3] conditional independence can be inferred from the covariance matrix by computing partial correlations. Instead of using the covariance matrix, we describe the following more intuitive way to obtain partial correlations: let P(X, Y, Z) be Gaussian, then X independent of Y given Z is equivalent to:

$$\text{corr}(X - \alpha Z, Y - \beta Z) = 0 \tag{3}$$

where α and β are the structure coefficients obtained from least square regression when regressing X on Z and Y on Z, respectively. Explicitly, they are given by:

$$\alpha = \text{Cov}(X,Z)/\text{Var}(Z) \tag{4}$$

$$\beta = \text{Cov}(Y,Z)/\text{Var}(Z) \tag{5}$$

Note, however, that in non-Gaussian distributions, vanishing of the partial correlation on the left-hand side of (2) is neither necessary nor sufficient for X independent of Y given Z. On the one hand, there could be higher order dependences not detected by the correlations. On the other hand, the influence of Z on X and Y could be non-linear and, in this case, it would not entirely be screened off by a linear regression on Z. This is why using partial correlations instead of independence tests can introduce two types of errors: namely accepting independence even though it does not hold, or rejecting it even though it holds (even in the limit of infinite sample size). Conditional independence testing is a challenging problem, and, therefore, we always trust the results of unconditional tests more than those of conditional tests.

To partly overcome these limitations of conditional independence testing, we also used 'partial HSIC' (we are not aware of any example of it in the literature, but it is a straightforward replacement of partial correlation), that is, performing an HSIC test on the residuals $X - \alpha Z$, $Y - \beta Z$. If their independence is accepted, then X independent of Y given Z necessarily holds. Hence, we have in the infinite sample limit only the risk of rejecting independence although it does hold, while the second type of error, namely accepting conditional independence although it does not hold, is only possible due to finite sampling, but not in the infinite sample limit.

[3] A vector-valued variable $(X_1, \ldots, X_d)$ is called multi-variate Gaussian if every linear combination $\Sigma_j c_j X_j$ is Gaussian distributed.

The conditional independence based approach can infer the causal direction between two variables A and B based on whether a third variable C has specific patterns of (in)dependency with A and B (Kwon & Bessler, 2011). Consider the case of two variables A and B, which are unconditionally independent, and then become dependent once conditioning on a third variable C. The only logical interpretation of such a statistical pattern in terms of causality (given that there are no hidden common causes) would be that C is caused by A and B (i.e. $A \rightarrow C \leftarrow B$, pattern which is known as a 'V-structure' or 'unshielded collider', represented for example by $X_1 \rightarrow X_3 \leftarrow X_2$ in Figure 1). Another illustration of how causal inference can be based on conditional and unconditional independence testing is provided by the example of a Y-structure in Box 1.

The conditional independence-based approach for causal identification seeks to apply logical rules to suggest how observed dependencies between variables should be causally oriented (see Pearl (2009) and Kwon & Bessler (2011) for surveys). The conditional independence-based approach has been used in several economic applications such as macroeconomic dynamics and vector autoregression models (Swanson & Granger, 1997; Demiralp & Hoover, 2003; Perez & Siegler, 2006; Moneta, 2008) as well as the analysis of corn price dynamics (Xu, 2017).

The conditional independence-based approach can help to "reduce the class of admissible causal structures among contemporaneous variables" (Moneta, 2008, p.276) by disproving certain specific causal relations in some cases (Bryant et al., 2009), although a drawback is that often it is not conclusive enough to deliver a unique set of causal orderings between variables (Moneta, 2008; Xu, 2017). Instead, ambiguities may remain and some causal relations will be unresolved. We therefore complement the conditional independence-based approach with other techniques: additive noise models, and non-algorithmic inference by hand. For an overview of these more recent techniques, see Peters, Janzing, and Schölkopf (2017), and also Mooij, Peters, Janzing, Zscheischler, and Schölkopf (2016) for extensive performance studies.

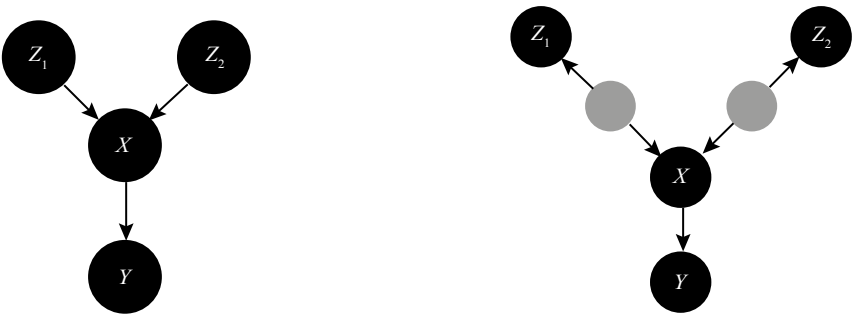
Box 1: Y-structures

Let us consider the following toy example of a pattern of conditional independences that admits inferring a definite causal influence from X on Y, despite possible unobserved common causes (i.e. in the case of Y-structures there is no need to assume causal sufficiency).

If the following four conditions are satisfied:

- Z_1 is independent of Z_2
- Z_1 and Z_2 become dependent when conditioning on X
- $\{Z_1, Z_2\}$ are dependent on Y without conditioning on X
- $\{Z_1, Z_2\}$ are independent of Y when conditioning on X

the figure below on the left ("Y-structure") is an example of a DAG entailing this pattern of conditional (in)dependences. Another example including hidden common causes (the grey nodes) is shown on the right-hand side. Both causal structures, however, coincide regarding the causal relation between X and Y and state that X is causing Y in an unconfounded way. In other words, the statistical dependence between X and Y is entirely due to the influence of X on Y without a hidden common cause, see Mani, Cooper, and Spirtes (2006) and Section 2.6 in Pearl (2009). Similar statements hold when the Y structure occurs as a subgraph of a larger DAG, and Z_1 and Z_2 become independent after conditioning on some additional set of variables. Scanning quadruples of variables in the search for independence patterns from Y-structures can aid causal inference.



The figure on the left shows the simplest possible Y-structure. On the right, there is a causal structure involving latent variables (these unobserved variables are marked in grey), which entails the same conditional independences on the observed variables as the structure on the left.

Implementation

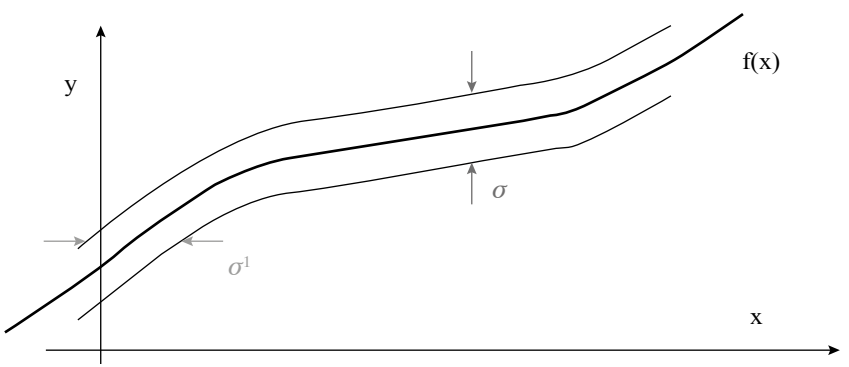
Since conditional independence testing is a difficult statistical problem, in particular when one conditions on a large number of variables, we focus on a subset of 5-8 variables. We first test all unconditional statistical independences between X and Y for all pairs (X, Y) of variables in this set. Then we test all conditional independences between X and Y, conditional on Z, for all possible triples (X, Y, Z). To avoid serious multi-testing issues and to increase the reliability of every single test, we do not perform tests for independences of the form X independent of Y conditional on Z_1,Z_2, ... Z_n, with n>1. We then construct an undirected graph where we connect each pair that is neither unconditionally nor conditionally independent. Whenever the number d of variables is larger than 3, it is possible that we obtain too many edges, because independence tests conditioning on more variables could render X and Y independent. We take this risk, however, for the above reasons. In some cases, the pattern of conditional independences also allows the direction of some of the edges to be inferred: whenever the resulting undirected graph contains the pattern X – Z – Y, where X and Y are non-adjacent, and we observe that X and Y are

independent but conditioning on Z renders them dependent, then Z must be the common effect of X and Y (i.e., we have a "v-structure" at Z, denoted as $X \rightarrow Z \leftarrow Y$). For this reason, we perform conditional independence tests also for pairs of variables that have already been verified to be unconditionally independent. From the point of view of constructing the skeleton, i.e., the DAG with undirected edges, the conditional independence tests would be redundant, but for orienting edges the conditional independence tests can be helpful. This argument, like the whole procedure above, assumes causal sufficiency, i.e., the absence of hidden common causes. It is therefore remarkable that the additive noise method below is in principle (under certain admittedly strong assumptions) able to detect the presence of hidden common causes, see Janzing et al. (2009).

Tool 2: Additive Noise Models (ANM)

Our second technique builds on insights that causal inference can exploit statistical information contained in the distribution of the error terms, and it focuses on two variables at a time. Causal inference based on additive noise models (ANM) complements the conditional independence-based approach outlined in the previous section because it can distinguish between possible causal directions between variables that have the same set of conditional independences. With additive noise models, inference proceeds by analysis of the patterns of noise between the variables (or, put differently, the distributions of the residuals).

Figure 2.
For y = f(x) + e, the 'width' of the noise is constant in one direction only, for non-linear f.



Source: Mooij, Peters, Janzing, Zscheischler, and Schölkopf (2016).

In particular, ANM is able to distinguish between $X \rightarrow Y$ and $Y \rightarrow X$ from the joint distribution $P_{X,Y}$ alone (Hoyer, Janzing, Mooij, Peters, & Schölkopf, 2009). ANMs can also be applied to discrete variables (Peters, Janzing, & Schölkopf, 2011) although at present there is no extensive evaluation of their performance.

Assume Y is a function of X up to an independent and identically distributed (IID) additive noise term that is statistically independent of X, i.e.,

$$Y = f_Y(X) + N_Y$$

where N_Y is independent of X. It can be shown that there is no additive noise model from Y to X in the 'generic case'[4], i.e., there is no function f_X such that,

$$X = f_X(Y) + N_X$$

with N_X independent of Y. Figure 2 visualizes the idea showing that the noise cannot be independent in both directions.

To see a real-world example, Figure 3 shows the first example from a database containing cause-effect variable pairs for which we believe to know the causal direction.[5] Up to some noise, Y is given by a function of X (which is close to linear apart from at low altitudes). Moreover, if we try to describe the altitude as a function of the temperature, the error term is not close to additive, but has a somewhat 'complex' structure, especially in the region of the y-axis corresponding to altitude zero (sea level). Phrased in terms of the language above, writing X as a function of Y yields a residual error term that is highly dependent on Y. On the other hand, writing Y as a function of X yields the noise term that is largely homogeneous along the x-axis. Hence, the noise is almost independent of X. Accordingly, additive noise based causal inference really infers altitude to be the cause of temperature (Mooij et al., 2016), which is certainly true: fixing a thermometer to a balloon would confirm that the temperature changes with the altitude, while heating a place would not change its altitude. Furthermore, this example of altitude causing temperature (rather than vice versa) highlights how, in a thought experiment of a cross-section of paired altitude-temperature datapoints, the causality runs from altitude to temperature even if our cross-section has no information on time lags. Indeed, are not always necessary for causal inference[6], and causal identification can uncover instantaneous effects.

The practical method for inferring causal directions works as follows:

(1) Perform a linear regression of Y on X, that is, find the function f_Y with

$$f_Y(x) := E[Y|x].$$

(2) compute the residual variable $N_Y := Y - f_Y(X)$, and

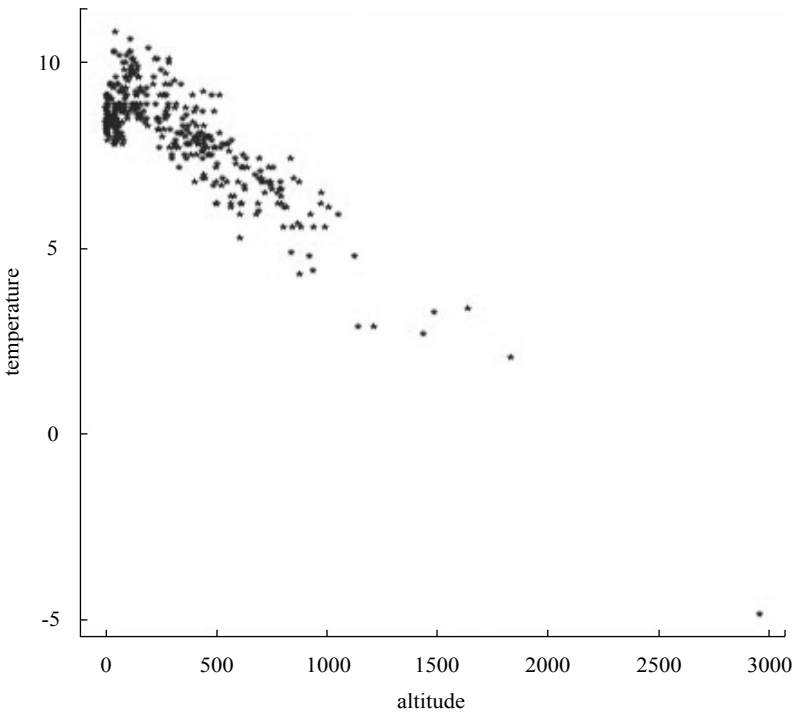
[4] The precise meaning of 'generic' here is complicated, see Hoyer, Janzing, Mooij, Peters, and Schölkopf, 2009; Peters, Janzing, and Schölkopf, 2017.

[5] Database with cause effect pairs: https://webdav.tuebingen.mpg.de/cause-effect/. Copyright for variable pairs can be found there.

[6] Granger causality is, under some conditions, also able to uncover instantaneous effects, see Figure 10.8b) and the corresponding explanations on page 207 in Peters, Janzing, and Schölkopf (2017).

(3) test whether N_Y is independent of X. Then do the same exchanging the roles of X and Y. If independence of the residual is accepted for one direction but not the other, the former is inferred to be the causal one. If independence is either accepted or rejected for both directions, nothing can be concluded. If a decision is enforced, one can just take the direction for which the p-value for the independence is larger.

Figure 3.
Scatter plot showing the relation between altitude (X) and temperature (Y) for places in Germany



Source: Mooij et al. (2016). Example taken from the database of cause effect pairs at https://webdav.tuebingen.mpg.de/cause-effect/.

This, however, seems to yield performance that is only slightly above chance level (Mooij et al., 2016). Otherwise, setting the right confidence levels for the independence test is a difficult decision for which there is no general recommendation. Conservative decisions can yield rather reliable causal conclusions, as shown by extensive experiments in Mooij et al. (2016). It should be emphasized that additive noise based causal inference does not assume that every causal relation in real-life can be described by an additive noise model. Instead, it assumes that if there is an additive noise model in one direction, this is likely to be the causal one. Hence, causal inference via additive noise models may yield some interesting insights into

causal relations between variables although in many cases the results will probably be inconclusive.

For a justification of the reasoning behind the likely direction of causality in Additive Noise Models, we refer to Janzing and Steudel (2010). The idea is that a joint distribution $P_{X,Y}$ that admits an additive noise model from X to Y is unlikely to be generated by the causal structure $Y \rightarrow X$ because this requires atypical adjustments between P_Y and $P_{X|Y}$. To show this, Janzing and Steudel (2010) derive a differential equation that expresses the second derivative of the logarithm of p(y) in terms of derivatives of log p(x|y). Therefore, for a given conditional $P_{X|Y}$, only very specific choices of P_Y generate an additive noise model from X to Y.

Mooij et al. (2016) provide a recent extensive evaluation of additive noise based inference on real and simulated data. They also make a comparison with other causal inference methods that have been proposed during the past two decades.[7] Additionally, Peters et al. (2011) discuss additive noise models in the context of variables that are not continuous but also discrete. In this paper, we apply ANM-based causal inference only to discrete variables that attain at least four different values.

To our knowledge, the theory of additive noise models has only recently been developed in the machine learning literature (Hoyer et al., 2009; Janzing & Steudel, 2010; Peters et al., 2011, 2017; Mooij et al., 2016) and has not yet been introduced into economics or business research. However, given that these techniques are quite new, and their performance in economic contexts is still not well-known, our results should be seen as preliminary (especially in the case of ANMs on discrete rather than continuous variables).

Further novel techniques for distinguishing cause and effect are being developed. Bloebaum, Janzing, Washio, Shimizu, and Schölkopf (2018), for instance, infer the causal direction simply by comparing the size of the regression errors in least-squares regression and describe conditions under which this is justified. Extensive evaluations, however, are not yet available.

Tool 3: Non-algorithmic inference by hand

The approach introduced in this section is more of a 'meta-method' than a method, which introduces techniques that are not fully automated, but used on a case-by-case, manual basis.

Since the innovation survey data contains both continuous and discrete variables, we would require techniques and software that are able to infer causal directions when one variable is discrete and the other continuous. Unfortunately, there are no off-the-shelf methods available to do this. Sun et al. (2006) and Janzing et al. (2009) propose a method that has been applied to a very limited number of data

[7] The real-world data experiments refer to the benchmark data set http://webdav.tuebingen.mpg.de/cause-effect/

sets. In the absence of methods for automated causal discovery, we can try to get hints on the causal direction by using our intuition and arguments that rely on the Principle of Algorithmically Independent Conditionals (Janzing & Schölkopf, 2010; Lemeire & Janzing, 2012). For the special case of a simple bivariate causal relation with cause and effect, it states that the shortest description of the joint distribution $P_{cause,effect}$ is given by separate descriptions of P_{cause} and $P_{effect|cause}$. This implies, in particular, that describing $P_{cause,effect}$ in terms of P_{cause} and $P_{effect|cause}$ is 'simpler' than describing it in terms of P_{effect} and $P_{cause|effect}$[8]. To illustrate this principle, Janzing and Schölkopf (2010) and Lemeire and Janzing (2012) show the two toy examples presented in Figure 4. In both cases we have a joint distribution of the continuous variable Y and the binary variable X. On the left-hand side, P_Y is a mixture of two Gaussians, each of which can be assigned to the cases $X = 0$ and $X = 1$, respectively. This joint distribution $P_{X,Y}$ clearly indicates that X causes Y because this naturally explains why P_Y is a mixture of two Gaussians and why each component corresponds to a different value of X. When the same distribution is generated via the causal structure $Y \rightarrow X$ there is, at first, no explanation of why P_Y consists of two modes and, second, no explanation is provided of why each of the Gaussians corresponds to one value of X.[9] Moreover, the distribution on the right-hand side clearly indicates that Y causes X because the value of X is obtained by a simple thresholding mechanism, i.e., $P_{X|Y}$ is a 'machine' receiving continuous input Y and generating the output $X = 0$ or $X = 1$, depending on whether Y is above a certain threshold. To generate the same joint distribution of X and Y when X is the cause and Y is the effect involves a quite unusual mechanism for $P_{Y|X}$. Then, $P_{Y|X}$ would be a 'machine' with binary input X whose output is one of the two sides of a truncated Gaussian, depending on the input X.

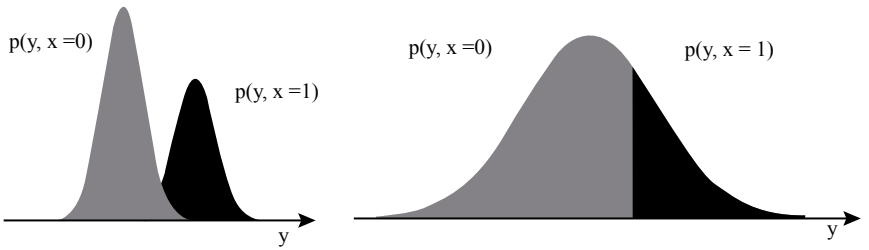
The examples show that joint distributions of continuous and discrete variables may contain causal information in a particularly obvious manner. There are, however, no algorithms available that employ this kind of information apart from the preliminary tools mentioned above. We therefore rely on human judgements to infer the causal directions in such cases (i.e. human-assisted or "supervised" machine learning, as emphasized in Mullainathan and Spiess, 2017). Below, we will therefore visualize some particular bivariate joint distributions of binaries and continuous variables to get some, although quite limited, information on the causal directions. Although we cannot expect to find joint distributions of binaries and

[8] A recent proposal to implement this principle in practice can be found in Budhathoki, Vreeken, and Origo (2018).

[9] To understand the last argument the reader may verify that for two overlapping Gaussians it requires quite sophisticated tuning of the conditional P(X|Y) in order to achieve that both conditional distributions P(Y|X=0) and P(Y|X=1) become Gaussians.

continuous variables (in our real data) for which the causal directions are as obvious as for the cases in Figure 4, we will still try to get some hints.[10]

Figure 4.
Left: visualization of a joint distribution of a binary variable X and a continuous variable Y for which it is reasonably clear that the causal direction reads X → Y. Right: joint distribution for which it is reasonably clear that the causal direction is Y → X.



Figures are taken from Janzing and Schölkopf (2010), Janzing et al. (2009), and Lemeire and Janzing (2012).

Finally, another tool that could help causal inference in the case of continuous variables is the Linear Non-Gaussian Acyclic Model (LiNGAM) developed by Shimizu, Hoyer, Hyvarinen, and Kerminen, 2006 (see e.g. Shimizu, 2014 for an overview) and introduced into economics by Moneta et al. (2013) and Lanne et al. (2017). LiNGAM uses statistical information in the (necessarily non-Gaussian) distribution of the residuals to infer the likely direction of causality. LiNGAM analysis was pursued by Xu (2017) to help to orient the DAG's causal relations which had remained unresolved after an initial analysis using the conditional independence-based approach. LiNGAM will be applied 'manually' on a case-by-case basis to obtain further insights into causal relations where possible.

DATA

We analyse data taken from the Community Innovation Surveys (CIS), which are based on the OECD's Oslo Manual, and were administered in several European

[10]Although from a different context, the following example of causal relations between a binary and a continuous variable may be of interest. There is an obvious bimodal distribution in data on the relationship between height and sex, with an intuitively obvious causal connection; and there is a similar but much smaller bimodal relationship between sex and body temperature, particularly if there is a population of young women who are taking contraceptives or are pregnant. In contrast, Temperature-dependent sex determination (TSD), observed among reptiles and fish, occurs when the temperatures experienced during embryonic or larval development determine the sex of the offspring. In one instance, therefore, sex causes temperature, and in the other, temperature causes sex, which fits loosely with the two examples (although we do not claim that these gender-temperature distributions closely fit the distributions in Figure 4).

countries to gather information on the innovative activities of firms. The CIS questionnaire can be found online.[11]

CIS data is perhaps the best-known dataset on firm-level innovative activity; it has been extensively analysed and mined by economists and innovation scholars (Mairesse & Mohnen, 2010; Hall & Jaffe, 2012). While previous datasets on firm-level innovation focused on R&D expenditures and patent counts, CIS data has shed valuable light on other aspects of firm-level innovative activity although it also has a number of drawbacks, such as being cross-sectional in nature (thus impeding the investigation of lagged effects, or controlling for time-invariant firm-specific heterogeneity), and also having few variables that can serve as valid instrumental variables.

Mairesse and Mohnen (2010) write:

> "Basically innovation survey data are of a cross-sectional nature, and it is always problematic to address econometric endogeneity issues and make statements about directions of causality with cross-sectional data. ... we have very few exogenous or environmental variables that can serve as relevant and valid instruments." (p.1138)

Moreover, data confidentiality restrictions often prevent CIS data from being matched to other datasets or from matching the same firms across different CIS waves. In addition, at time of writing, the 2008 wave was already rather dated. Finally, another caveat is that many CIS questionnaire responses are evaluated subjectively, and there may be an individual-specific common cause that is correlated across a respondent's questionnaire responses, which could be a further obstacle to causal search.

Given these strengths and limitations, we consider the CIS data to be ideal for our current application, for several reasons:

- It is a very well-known dataset – hence the performance of our analytical tools will be widely appreciated
- It has been extensively analysed in previous work, but our new tools have the potential to provide new results, therefore enhancing our contribution over and above what has previously been reported
- Standard methods for estimating causal effects (e.g. instrumental variables, regression discontinuity design, panel data econometrics) are difficult or impossible to apply
- Most variables are not continuous but categorical or binary, which can be problematic for some estimators but not necessarily for our techniques
- Causal estimates based on CIS data will be valuable for innovation policy

[11] See http://ec.europa.eu/eurostat/web/microdata/community-innovation-survey [last accessed June 15, 2017].

To be precise, we focus on the 2008 wave of the CIS, with our raw data covering 16 countries: Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Germany (DE), Estonia (EE), Spain (ES), Hungary (HU), Ireland (IE), Italy (IT), Lithuania (LT), Latvia (LV), Norway (NO), Portugal (PT), Romania (RO), Slovenia (SI), and Slovakia (SK).

Our data have been deliberately noise-contaminated to anonymise the firms (Mairesse & Mohnen, 2010, p1148; see also Eurostat, 2009). This was done by capping the continuous variables relating to sales and R&D expenditure, and, for the largest values, the true values are not reported, but instead the largest values are approximated. These countries are pooled together to create a pan-European database. This reflects our interest in seeking broad characteristics of the behaviour of innovative firms, rather than focusing on possible local effects in particular countries or regions.

Observations are then randomly sampled. We do not try to have as many observations as possible in our data samples for two reasons. First, due to the computational burden (especially for additive noise models). Second, our analysis is primarily interested in effect sizes rather than statistical significance. We believe that in reality almost every variable pair contains a variable that influences the other (in at least one direction) when arbitrarily weak causal influences are taken into account. However, we are not interested in weak influences that only become statistically significant in sufficiently large sample sizes. Therefore, our data samples contain 2000 observations for our main analysis, and 200 observations for some robustness analysis.[12]

The CIS databases of the sixteen countries differ in terms of number of firms, hence the representativeness of the country's overall economy (in terms of representativeness of firms of different sizes, and firms in manufacturing vs. services sectors, etc.). There is slight variation across countries regarding which questions are asked and the order in which they appear in the questionnaire (Mairesse & Mohnen, 2010). Furthermore, the data does not accurately represent the proportions of innovative vs. non-innovative firms across European countries. We focus on firms with non-zero in-house R&D expenditure. We do not make specific efforts to distinguish between firms in different sectors for two reasons: previous research has emphasized the heterogeneity of innovation patterns within the same sector, and sector of activity has a low explanatory power in explaining firm-level innovation behaviour (Leiponen & Drejer, 2007; Srholec & Verspagen, 2012).[13] In keeping with the previous literature that applies the conditional independence-based approach (e.g. Swanson & Granger, 1997; Xu, 2017) and additive

[12] In the machine learning literature, it is not unusual to throw away observations in order to save computational time. Google throws away 99.9% of observations when it does analysis on its own data (see Varian, 2014, p4: "At Google, for example, I have found that random samples on the order of 0.1 percent work fine for analysis of business data.")

[13] Srholec and Verspagen (2012) summarize thus: "[h]eterogeneous, not sectoral or national, is the adjective that should be used to describe patterns of how firms innovate." (p.1247)

noise models (Mooij et al., 2016) and LiNGAM (Moneta et al., 2013), and in contrast to the usual linear regression approach, we do not include control variables in our analysis. This is for several reasons. First, the predominance of unexplained variance can be interpreted as a limit on how much omitted variable bias (OVB) can be reduced by including the available control variables because innovative activity is fundamentally difficult to predict.

Mairesse and Mohnen (2010) found the following:

> "the unexplained residual, that is, the measure of our ignorance in matters of innovation, is larger than the explained part of the share of total sales due to new products, even more in low tech than in high tech sectors." (p.1142)

Second, including control variables can either correct or spoil causal analysis depending on the positioning of these variables along the causal path, since conditioning on common effects generates undesired dependences (Pearl, 2009). Third, in any case, the CIS survey has only a few control variables that are not directly related to innovation (i.e. exporting status, sector and region dummies, and business group affiliation).

For ease of presentation, we do not report long tables of p-values (see instead Janzing, 2016), but report our results as DAGs.

Hence, we are not interested in international comparisons.[14] Nevertheless, we argue that this data is sufficient for our purposes of analysing causal relations between variables relating to innovation and firm growth in a sample of innovative firms.

ANALYSIS

In this section, we present the results that we consider to be the most interesting on theoretical and empirical grounds. The three tools described in Section 2 are used in combination to help to orient the causal arrows. Our results are presented in the form of (partially) Directed Acyclic Graphs (DAGs), following Pearl (2009) and Spirtes et al. (2000). (To be precise, we present partially directed acyclic graphs (PDAGs) because the causal directions are not all identified.) Random variables $X_1 \ldots X_n$ are the nodes, and an arrow from X_i to X_j indicates that interventions on X_i have an effect on X_j (assuming that the remaining variables in the DAG are adjusted to a fixed value). Arrows represent direct causal effects, but note that the distinction between direct and indirect effects depends on the set of variables included in the DAG. Here, we assume that there is no absolute distinction between 'direct' and 'indirect' influence. A line without an arrow represents an undirected relationship – i.e. a statistical association rather than a causal effect – where the direction of causality was not clearly resolved.

[14] See Mairesse and Mohnen (2010), "it is heroic to make international comparisons when the questionnaires differ in their content, the order of the questions and their formulations, and when the sampling of respondents differs across countries." (p.1140)

Case 0: sanity check

We begin with a 'sanity check' to verify that our data-driven analysis does not deliver results that are theoretically nonsensical. We investigate the causal relations between two variables where the true causal relationship is already known: i.e. that a firm's sales in 2006 cause a firm's sales in 2008 and not vice-versa. Indeed, the causal arrow is suggested to run from 2006 sales to 2008 sales, which is in line with expectations.[15]

Mooij et al. (2016, Appendix D) provide further sanity checks for simulated data, as well as real-world variable-pairs where the direction of causality is obvious, such as altitude → precipitation; latitude → temperature; age → wage per hour; day of the year → temperature; size of apartment → monthly rent; and age → relative spinal bone mineral density. They conclude that Additive Noise Models (ANM) that use HSIC perform reasonably well, provided that one decides only in cases where an additive noise model fits significantly better in one direction than the other.

Case 1: funding for innovation

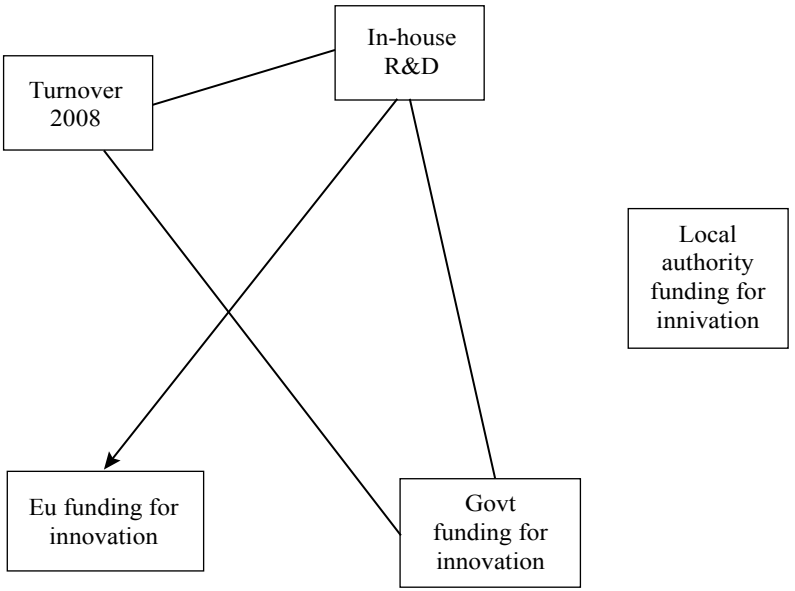
A large literature in the economics of innovation has sought to evaluate the effectiveness of public schemes to provide funding for firms' innovative activity and, more specifically, R&D investments. While R&D investing firms are often associated with receipt of funding, the crucial question is whether funding causes R&D investment, or whether R&D investment causes receipt of funding. Standard econometric tools for causal inference, such as instrumental variables, or regression discontinuity design, are often problematic. The empirical literature has applied a variety of techniques to investigate this issue, and the debate rages on. Wallsten (2000) applies a three-stage least squares model and finds that R&D grants totally crowd out firm-financed R&D spending. Aerts and Schmidt (2008) reject the crowding out hypothesis, however, in their analysis of CIS data using both a non-parametric matching estimator and a conditional difference-in-differences estimator with repeated cross-sections (CDiDRCS). Hussinger (2008) finds that public R&D subsidies have a positive effect on treated firms' R&D intensity, using parametric and semiparametric two-step selection models. Howell (2017) applies a sharp regression discontinuity design (RDD) approach and observes that early-stage R&D grants have significant causal effects on firms' outcomes, while the performance of later stage R&D grants is rather disappointing.

Our analysis, in Figure 5, shows that in-house R&D causes EU-level funding, rather than vice versa. This suggests that EU-level funding has no additionality – instead funding is given as windfalls to firms that have already made their R&D investments. In-house R&D, and also total sales, are positively associated with government funding, but there is no evidence that it is funding that improves

[15]Details are in Janzing (2016, Section 6.5).

the performance of these firms rather than vice versa. Interestingly, and in line with previous research (see Hashi & Stojcic, 2013, p359, who analyse CIS4 data for sixteen European countries), unlike funding from European or national government sources, funding from regional authorities seems quite disconnected (and perhaps irrelevant) for firm size and innovative activity.

Figure 5.
Partially directed graph resulting from the independence pattern of rrdinx (in-house R&D), turn08m (turnover in 2008), funeu (EU funding for innovation), fungmt (central government funding for innovation), funloc (local authority funding of innovation).



Source: Authors' own analysis.

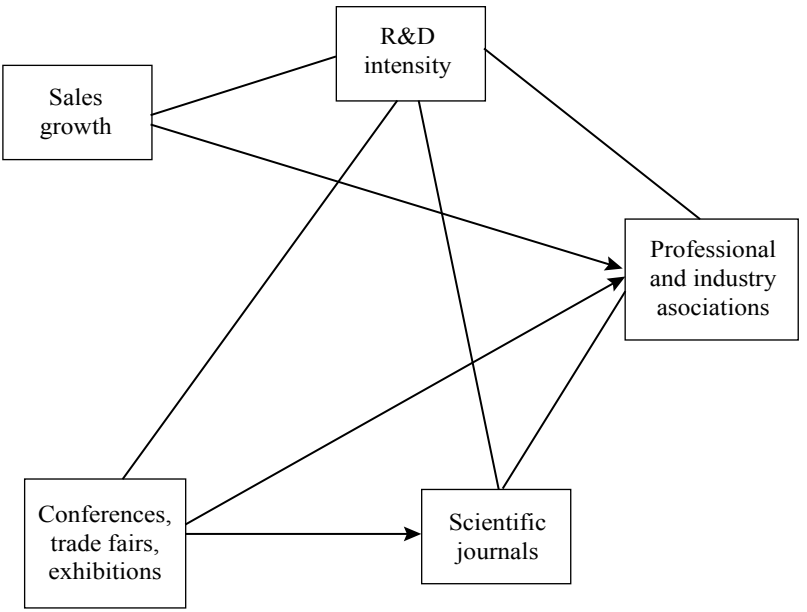
Case 2: information sources for innovation

Our second example considers how sources of information relate to firm performance. In the age of open innovation (Chesbrough, 2003), innovative activity is enhanced by drawing on information from diverse sources. However, the relationships between external information sources, R&D investment, and innovation, are complex and not well understood (Laursen & Salter, 2006). Previous research on this issue using CIS data has reported associations but not causal effects (Laursen & Salter, 2006; Vega-Jurado, Gutiérrez-Gracia, & Fernández-de-Lucio, 2009). One policy-relevant example relates to how policy initiatives might seek to encourage firms to join professional industry associations in order to obtain valuable information by networking with other firms. A German initiative requires

firms to join a German Chamber of Commerce (IHK), which provides support and advice to these firms,[16] perhaps with a view to trying to stimulate innovative activities or growth of these firms. However, our results suggest that joining an industry association is an outcome, rather than a causal determinant, of firm performance. Figure 6 shows that having professional and industry associations as a source of information is caused by sales growth, and is positively associated with R&D intensity. This is in contrast with Yam, Lo, Tang, and Lau (2011), who observe a statistical relationship between sources of innovation and R&D capability, and rely on theoretical assumptions to interpret this as evidence that it is the source of information that causes R&D capability.

Conferences, as a source of information, have a causal effect on treating scientific journals or professional associations as information sources.

Figure 6.
Partially directed graph resulting primarily from the independence pattern of rdint (R&D intensity), gr_sales (sales growth), scon (sources of information: conferences, trade fairs, exhibitions), sjou (sources of information: scientific journals and trade/technical publications), spro (professional and industry associations). The edge scon-sjou has been directed via discrete ANM.



Source: Authors' own analysis.

[16] All German companies registered in Germany, with the exception of handicraft businesses, the free professions, and farms, are required by law to join a chamber of commerce. See https://www.dihk.de/en (last accessed June 20th, 2017).

Case 3: innovation expenditures

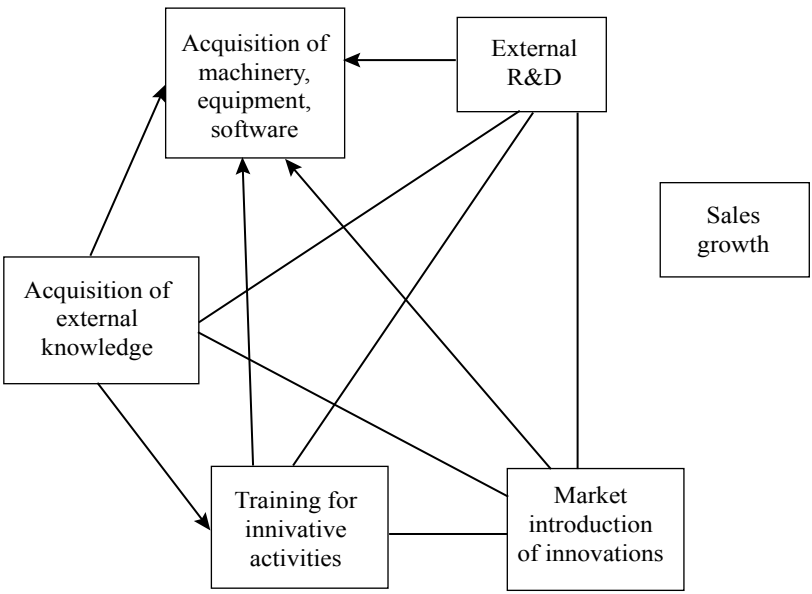
Although R&D investment is often the first choice of indicator of innovative activity, only a small subset of firms will have positive R&D expenditure, which has led scholars to consider other useful indicators of innovation such as acquisition of machinery/equipment/software, and training (Hall & Jaffe, 2012). In this example, we take a closer look at the different types of innovation expenditure, to investigate how innovative activity might be stimulated more effectively. Previous research has shown that suppliers of machinery, equipment, and software are associated with innovative activity in low- and medium-tech sectors (Heidenreich, 2009). Indeed, acquisition of machinery, equipment, and software plays an important role in firm-level innovation, accounting for between 30% and 90% of innovation expenditures across sectors (see Hughes & Mina, 2012, p5 for UK evidence). However, the Open Innovation paradigm suggests that innovative activity is stimulated by external R&D and external knowledge acquisition (Chesbrough, 2003). The following question therefore arises: should firms be encouraged to acquire external knowledge or machinery/equipment/software? Our results suggest the former. Acquisition of external knowledge has knock-on effects on acquisition of machinery/equipment/software, as well as on training; and training in turn has an impact on acquisition of machinery/equipment/software. Furthermore, external R&D and market introduction of innovations both have causal effects on acquisition of machinery/equipment/software, but this latter has no causal effect on the other variables investigated in this case. Hence, attempts to stimulate expenditures on machinery/equipment/software would not be an effective policy, because these expenditures are stimulated by other innovation expenditures anyway, and because they have no further impacts on other variables.

CONCLUSION

For a long time, causal inference from cross-sectional innovation surveys has been considered impossible. This article introduced a toolkit to innovation scholars by applying techniques from the machine learning community, which includes some recent methods. In particular, three approaches were described and applied: a conditional independence-based approach, additive noise models, and non-algorithmic inference by hand. These techniques were then applied to very well-known data on firm-level innovation: the EU Community Innovation Survey (CIS) data in order to obtain new insights. Three applications are discussed: funding for innovation, information sources for innovation, and innovation expenditures and firm growth. Our results – although preliminary – complement existing findings by offering causal interpretations of previously-observed correlations. Regarding funding for innovation, our results suggest that in-house R&D is a cause, rather than an effect, of receiving EU funding. Regarding information sources, we found that interest in professional & industry associations is caused by sales growth and conferences / trade fairs / exhibitions (and this latter is a cause of interest in scientific

journals). Regarding innovation expenditures, we find a number of results, in particular that acquisition of machinery / equipment / software occurs towards the end of the causal ordering, being causally influenced by several other dimensions of innovation expenditure.

Figure 7.
Partially directed graph resulting from the independence pattern of rrdex (external R&D), rmac (acquisition of machinery, equipment, software), roek (acquisition of external knowledge), rtr (training for innovative activities), rmar (market introduction of innovations), gr_sales. Inference was also undertaken using discrete ANM.



Source: Authors' own analysis.

Future work could extend these techniques from cross-sectional data to panel data. This will presumably be a relatively trivial extension – considering that the most challenging task when identifying a panel regression model such as a structural vector autoregression is first identifying the matrix of instantaneous causal effects in the cross-section (Hyvarinen, Shimizu, & Hoyer, 2008; Moneta et al., 2013). Future work could also investigate which of the three particular tools discussed above works best in which particular context.

Our analysis has a number of limitations, chief among which is that most of our results are not significant. In most cases, it was not possible, given our conservative thresholds for statistical significance, to provide a conclusive estimate of what is causing what (a problem also faced in previous work, e.g. Moneta, 2008; Xu, 2017).

Nevertheless, we maintain that the techniques introduced here are a useful complement to existing research. We consider that even if we only discover one causal relation, our efforts will be worthwhile.[17] Another limitation is that more work needs to be done to validate these techniques (as emphasized also by Mooij et al., 2016), to better understand their reliability. Other limitations, that constitute areas for further research, would be to investigate whether our results are sensitive to our choice of sample (in particular, our focus on R&D investors) or whether our results vary across sectors or across countries.

This paper sought to introduce innovation scholars to an interesting research trajectory regarding data-driven causal inference in cross-sectional survey data. Our aim is to draw attention to these techniques, in the hope that they will be further applied and developed, as another tool in the econometrician´s toolbox. Given the perceived crisis in modern science concerning lack of trust in published research and lack of replicability of research findings, there is a need for a cautious and humble cross-triangulation across research techniques. We hope to contribute to this process, also by being explicit about the fact that inferring causal relations from observational data is extremely challenging. We should in particular emphasize that we have also used methods for which no extensive performance studies exist yet.

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[17]This idea was expressed long ago by Democritus (460-370 BCE): "I would rather discover one causal law than be King of Persia."

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ACERCA DE CUADERNOS DE ECONOMÍA

La revista *Cuadernos de Economía* es publicada semestralmente por la Escuela de Economía de la Facultad de Ciencias Económicas (Universidad Nacional de Colombia). Es una de las más antiguas del país en el área económica. Su primera edición se realizó durante el primer semestre de 1979.

Nuestra publicación está disponible en índices y bases de datos nacionales e internacionales, tales como SCOPUS, Redalyc, SciELO Brasil, EBSCO, ESCI (Clarivate Analytics) / Thomson Reuters Web of Science (antiguo ISI)- SciELO Citation Index, Dialnet, Latindex -Sistema regional de información en línea, CIBERA (Biblioteca Virtual Iberoamericana España / Portugal, Ulrich's Directory, ProQuest, DOAJ (Directory of Open Access Journals), CLASE -Citas Latinoamericanas en Ciencias Sociales y Humanidades, IBSS -International Bibliography of the Social Sciences, e-revistas, HLAS -Handbook of Latin American Studies, RePEc -Research Papers in Economics, CAPES -Portal Brasilero de Información Científica, SSRN (Social Sciences Research Network), Econlit -Journal of Economic Literature (JEL), DoTEc -Colombia, Publindex, LatAm-Studies y Econpapers.

La revista tiene como objetivo divulgar, en el ámbito académico nacional e internacional, los avances intelectuales en teorías, metodologías y aplicaciones económicas, así como los resultados de investigaciones y trabajos especializados.

Su público está integrado por académicos (investigadores, docentes y estudiantes universitarios), miembros de instituciones gubernamentales y de entidades privadas, que se ocupen del estudio de la teoría económica, la política económica, el desarrollo socioeconómico y otros temas de interés para la disciplina.

El Editor y el Consejo Editorial de Cuadernos de Economía son las instancias que deciden sobre la publicación de las contribuciones. Es importante aclarar que el envío de material no exige su publicación y que el contenido de los artículos es responsabilidad de los autores y no compromete, de ninguna manera, a la revista o a la institución.

El autor interesado en someter a evaluación una contribución, debe hacerla llegar a la revista, conforme a las especificaciones contempladas en las *pautas para autores*. Esta información se encuentra disponible al final de cada número y en el sitio web: http://www.ceconomia.unal.edu.co.

Los evaluadores son seleccionados de acuerdo con sus conocimientos en los tópicos cubiertos por cada artículo. La evaluación toma en cuenta aspectos como la originalidad del contenido, el rigor conceptual, los aspectos metodológicos, la claridad y la coherencia, tanto en la argumentación como en la exposición, y la pertinencia de las conclusiones.

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La revista *Cuadernos de Economía* toma en consideración, para su publicación, contribuciones académicas inéditas, artículos de investigación, revisiones bibliográficas, debates y reseñas analíticas de libros, en español, inglés, francés o portugués, que no hayan sido propuestos en otras revistas académicas.

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La recepción de artículos se realiza durante todo el año. La revista podrá desestimar la publicación de un manuscrito si, por decisión interna, se determina que no cumple conciertos estándares académicos o editoriales. Los manuscritos que pasen la revisión inicial, serán enviados a evaluadores.

Con el fin de garantizar la imparcialidad de la evaluación emitida, nuestra publicación emplea el sistema de arbitraje doble ciego, es decir, que tanto los evaluadores como los autores permanecen anónimos.

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La evaluación toma en cuenta aspectos como la originalidad del contenido, el rigor conceptual, los aspectos metodológicos, la claridad y la coherencia (tanto en la argumentación como en la exposición), y la pertinencia de las conclusiones. Los resultados del arbitraje pueden ser: aprobado sin modificaciones, publicación sujeta a incorporación de cambios y observaciones, reescritura del documento y rechazo del material. La tasa de rechazo de materiales sometidos a evaluación durante 2018 fue de 78%.

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1. Someter un artículo a Cuadernos de Economía supone el compromiso, por parte de los autores, de no someterlo simultáneamente a otras publicaciones, ya sea en forma parcial o completa.
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La revue a l'objectif de divulguer, dans l'enceinte académique nationale et internationale, les avances intellectuelles dans des théories, des méthodologies et des applications économiques, ainsi que les résultats de recherches et de travaux spécialisés.

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Le processus de postulation se fait par le système de gestion éditoriale OJS et les documents doivent être joints dans le link suivant http://bit.ly/ZsvX1j.

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Número
70
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N.° 67
enero - marzo

E-ISSN 2248-6968 ISSN 0121-5051

INNOVAR

REVISTA DE CIENCIAS ADMINISTRATIVAS Y SOCIALES

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Categoría C en el Índice Bibliográfico Nacional de Colciencias

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UNIVERSIDAD PEDAGÓGICA Y TECNOLÓGICA DE COLOMBIA
ESCUELA DE ECONOMÍA

ISNN 0120-3053
E-ISSN 2256-5779

VOL 37, N° 66
JUL - DIC 2018

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Apuntes del Cenes se encuentra en: ESCI (WoS) - Scielo - RedAlyC - EBSCO - ProQuest - EconLit - DOAJ - Dialnet - Latindex - DOTEC - REPEC - ERIH PLUS - Publindex Categoría B - Econpapers - EconBib - Bibilat - REDIB - CrossRef - CLASE - SHERPA ROMEO - Academia

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Problemas del DESARROLLO
REVISTA LATINOAMERICANA DE ECONOMÍA

ISSN: 0301-7036

Volumen 49, número 195, octubre-diciembre 2018

Número actual

Publicación trimestral
Instituto de Investigaciones Económicas, UNAM
Suscripciones y ventas: revprode@unam.mx
Teléfono: (52-55) 56-23-01-05

http://www.probdes.iiec.unam.mx

81
DESARRO. SOC., segundo semestre 2018
ISSN 0120-3584, E-ISSN 1900-7760

Revista Desarrollo y Sociedad

CEDE
Centro de Estudios sobre Desarrollo Económico

Universidad de los Andes
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Cuadernos de Economía, 37(75)
se terminó de editar, imprimir y encuadernar
en Proceditor, en diciembre de 2018,
con un tiraje de 200 ejemplares,
sobre papel bond blanco bahía de 70 g.
Bogotá, D. C., Colombia.

CUADERNOS DE ECONOMÍA 75

CONTENIDO

ARTÍCULOS

ISSN 0121-4772