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FULL ARTICLE

Regional characteristics and the decision to innovate in a developing country: A multilevel analysis of Ecuadorian firms

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Abstract

This is the first study that uses multilevel modelling to analyse regional influence on the decision to invest in innovation activities of firms in a single developing country, Ecuador. Our results indicate that the decision to invest in R&D and in other innovation activities are conditioned by the region in which the firm is located. Regional loan volume, orientation towards knowledge exploitation and intra-regional-sectorial R&D spillovers are positively associated with both types of innovation activities, while regional levels of co-operation and inter-regional R&D spillovers are only positively associated with the probability of investing in other innovation activities.

KEYWORDS
co-operation, innovation activities, knowledge exploitation, R&D, regional innovation system

JEL CLASSIFICATION
C21; O31; R12

1 | INTRODUCTION

It is widely recognized that a firm's capability to become involved in innovation projects is constrained by the technological and institutional conditions of its environment (Lundvall, 1992). The decision to invest in innovation depends on the presence of a number of external factors, such as access to qualified personnel, sources of financing and information, and an environment that facilitates knowledge transfer. As the innovation process is frequently based on the interactions between different agents, which tend to occur within a geographic area, firms are ultimately more likely to invest in innovation in regions with greater knowledge exchange.

Most empirical studies recognize that innovation depends on both firms' characteristics and the particularities of their context (Goedhuys et al., 2013). Conventional empirical analysis has, however, been based on the analysis of individual data or ecological data, despite the former being vulnerable to the atomistic fallacy and the latter, to the ecological fallacy (Snijders & Bosker, 2012). Individual data studies commonly capture higher complexity by controlling contextual differences out through the use of dummy variables; but, this strategy removes contextual variance, losing important information (Bell & Jones, 2015; Neira et al., 2018). These studies thus do not permit accurate evaluation of the extent to which geographical conditions affect firms' decision to invest in innovation or determination of the regional characteristics that explain firm-level differences. Analysis of these issues requires recognizing the hierarchical structure of the data and applying multilevel models (Srholec, 2010). Multilevel models are an appropriate instrument to analyse the systemic nature of innovation due to their ability to capture contextual effects on individual decisions.

Our study aims to analyse the extent to which the decision to invest in innovation activities is conditioned by the region[1] in which the firm is located. To achieve this goal, we use multilevel logit models, which separate the variance in the decision to invest in innovation into two components, one due to firm-level determinants and the other to aggregate-level determinants. Only Aarstad et al. (2019) have estimated a logit multilevel model on the decision to invest in R&D. Other authors, such as López-Bazo and Motellón (2018), have estimated logit multilevel models on dependent variables related to firms' innovative performance.[2] This paper, however, is the first multilevel study to analyse the decision to invest in innovation activities in a single developing country,[3] Ecuador. Ecuador is a middle-income Latin-American country specialized in low value-added goods, whose total investment in R&D does not exceed 0.4% of GDP.

Our study is also the first to compare results for two different innovation input variables, investment in R&D and in other innovation activities.[4] In our sample from the 2015 Ecuadorian Innovation Survey (ENAI), 18% of the firms declared investments in R&D, while 40% declared investments in other innovation activities. Analysing other innovation activities is crucial for developing countries, given that most firms invest in these activities to introduce new products and processes. Moreover, our focus on the regional influence on the decision to invest in innovation in a developing country is consistent with literature stressing that external conditions are important for understanding the kind of technological capabilities that firms in these countries possess (Cirera & Maloney, 2017; Lall, 1992).

Regions in Ecuador differ in terms of infrastructure, specialized workforce, proximity to financial institutions, local public policies and even cultural aspects. Our study seeks to contribute to the regional innovation literature by examining whether five characteristics of Ecuadorian Regional Innovation Systems (RISs) explain the probability that firms invest in R&D and in other innovation activities. Our results indicate that regional loan volume, orientation towards knowledge exploitation and intra-regional-sectorial R&D spillovers are positively associated with both types of innovation activities, while regional levels of co-operation and inter-regional R&D spillovers are only positively associated with the probability of investing in other innovation activities.

The rest of this paper is organized as follows. Section 2 reviews the literature on internal and contextual determinants of the decision to invest in innovation activities. Section 3 describes the data and methodology. Section 4 discusses the results. Finally, Section 5 concludes. An online Supplementary Appendix provides additional details.

2 | DECISION TO INVEST IN INNOVATION ACTIVITIES

A firm's decision to invest in innovation depends both on internal and external factors. Internal factors refer to the characteristics of the firms that make them more inclined to invest in innovation. External factors are those related to the sector to which the firm belongs and the region where it is located.

2.1 | Internal factors

Based on a review of empirical studies, Becheikh et al. (2006) identified four categories of firm-level variables: the general characteristics of the firm, its strategic orientation the structuring of its activities and its functional assets.

The general characteristics of the firm comprise mainly four variables which are expected to positively influence the decision to invest in innovation: size, age, ownership structure, and past performance. Variables related to the strategic orientation of the firm refer to its level of diversification and internalization; alternatively, to other specific events such as mergers and acquisitions. These strategies influence the expected returns of innovation activities and the competitive pressures that firms face to innovate. A firm's internal factors associated with the structuring of its activities refer to variables related to its organizational structure and culture. Finally, variables associated with functional assets refer to the firm's financial capacity, financial constraints and human resources (Brown et al., 2012). Studies on the financing of innovation have also examined the gap between the costs of financing R&D through internal and external sources. Given the information asymmetries between firms' managers and financers, it is generally considered that R&D-intensive firms should be more inclined to rely on internal funds (Hall, 2002).

Evidence on the impact of these determinants of firms' innovation activities in developing countries shows varying and contradictory results (Becheikh et al., 2006). Nevertheless, innovation surveys reveal that innovative firms are larger and have a larger number of qualified employees (Arocena & Sutz, 2000).

2.2 | External factors

First, a firm's decision to invest in innovation is influenced by the economic sector to which it belongs. According to Cohen (1995), there are three factors creating a different structure of incentives for innovation in each sector: technological opportunities, demand conditions, and appropriability conditions. Technological opportunities refer to the likelihood of converting an investment into new products or processes. Therefore, the better the sectorial conditions relating to science and technology, the greater the incentives to invest in innovation. High demand also leads firms to invest in innovation, given that the larger the size of the market, the greater the returns that can be expected from innovation. Finally, sectors also differ in terms of appropriability conditions, which directly affect firms' innovation decisions, as they influence their ability to recover the fruits of their investments.

The rest of external factors are those related to the region where the firm is located. The systemic approach to the study of innovation argues that firms must be analysed as parts of broader innovation systems because projects to develop new technologies are carried out through interactions among agents within an institutional framework (Lundvall, 1992). Due to the tacit nature of much of the knowledge necessary to innovate, these interactions also tend to occur in a specific geographic area (Camagni & Capello, 2005). Emphasis is placed on the constraints that the characteristics of RISs impose on firms' innovation activities. The effect follows from several factors such as infrastructure, specialized workforce, proximity to potential partners and financial institutions, public sector initiatives and because proximity develops trust and social capital. In the case of developing countries, due to the heterogeneity in external factors of innovation depending on the specific region, a firm's location can influence its decision of whether or not to invest in innovation activities. We therefore propose the following hypothesis:

> **H1.** There is a set of factors, whether measurable or not, which affect the decision of firms in the same region to invest (or not) in R&D and in other innovation activities, and which are common to firms located in the same region.

RISs may influence firms' decisions to invest in innovation through different channels and it is unlikely to have information on each and all of them. Most multilevel studies in the field of innovation have analysed the influence of RISs characteristics on different variables related to firms' innovative performance (Barasa et al., 2017; Bellmann et al., 2018; López-Bazo & Motellón, 2018; Naz et al., 2015; Srholec, 2010, 2011; Srholec & Žížalová, 2013). They generally indicate that the quality of innovation systems (national or subnational) explains differences in firms' innovative performance, that various regional characteristics influence this performance, and that regional influence could differ from firm to firm. The only multilevel study analysing regional influence on firms' decision to invest in innovation activities is the one by Aarstad et al. (2019), which examines whether the industrial structures of Norway's 89 regions affect the decision to invest in R&D and R&D intensity. Their results indicate that being located in regions with unrelated, diversified, and fragmented industry structures increases both the probability and amount of R&D investment.

In this paper, we analyse the influence of five characteristics of Ecuadorian RISs on firms' innovation activities: volume of loans to firms, orientation towards knowledge exploitation, degree of co-operation in innovation activities, intra-regional-sectorial R&D spillovers and inter-regional R&D spillovers.

A fundamental characteristic of RISs for stimulating innovation is the strength of their financial system. Evidence indicates that financial systems are a fundamental factor in explaining differences in innovation among sectors and regions (Block, 2002). Although innovation activities tend to be financed through internal resources,[5] many firms turn to external sources. As Hughes (2014) indicates, given that complementary public investment and support for innovation vary across places, we may expect different systems of financial relationships to exist. Therefore, one might expect to find clustered national configurations of innovative activity and financing. Consequently, it is likely that firms located in regions with a stronger financial system are more likely to invest both in R&D and other innovation activities. Although firms located in regions with strong financial systems are expected to be more likely to invest in innovation activities, there is no evidence on what kind of innovation activities are more likely to be funded from external sources. However, as Hall and Lerner (2010) indicate, R&D activities might be more difficult to fund externally, since there is often a wedge between the rate of return required by the innovator and that required by external investors. R&D activities are likely to exhibit greater information asymmetries related to the fact that an innovator frequently has better information about the likelihood of success and the nature of the innovation project than potential investors. Reducing such asymmetry is often not possible due to the ease of imitation of new ideas. Thus, the strength of financial systems should be more related to the decision to invest in other innovation activities. We therefore propose the following hypothesis:

H2. The strength of the regional financial system positively influences firms' decision to invest in R&D and in other innovation activities, but mainly in other innovation activities.

Another essential characteristic of the RISs is whether they are more oriented towards knowledge generation or knowledge exploitation activities. Regions oriented towards knowledge generation are those in which R&D is performed predominantly by research institutions. In regions oriented towards knowledge exploitation, in contrast, R&D is performed primarily by firms. Evidence indicates that firms in regions oriented towards knowledge exploitation tend to be less likely to abandon their innovation activities (Cruz-Castro et al., 2018). In developing countries there is low reliance on local knowledge institutions and firms consider that external relations with universities and public research centers are less important than ties with suppliers, customers or foreign firms (Arocena & Sutz, 2000). According to the ENAI, between 2012 and 2014 only 6.5% of innovative firms had co-operated with universities in the development of new technologies. Therefore, we expect firms in regions oriented towards knowledge exploitation to tend to be more likely to invest in both types of innovation activities. Thus, we propose the following hypothesis:

H3. Regional orientation towards knowledge exploitation positively influences the decision to invest in R&D and in other innovation activities.

Further, as the internalization of external knowledge requires interaction through co-operating relationships, another regional characteristic that may affect the decision to invest in innovation is the degree of technological co-operation, since it is related to the availability and quality of external knowledge. In other words, a firm's decision to invest in innovation depends on how the regional knowledge base is being exploited and expanded through the interaction between the different actors (Schmutzler & Lorenz, 2018). What is particular to developing countries is that most co-operation relationships do not involve formal R&D projects but seek primarily to obtain technological information and set up training activities and technical support for employees (Fernández-Sastre & Vaca-Vera, 2017). Hence, these activities are more related to investments in other innovation activities. However, given that it is still plausible to consider that this regional characteristic influences both the decision to invest in R&D and in other innovation activities, we propose the following hypothesis:

> **H4.** The degree of regional innovative co-operation positively influences the decision to invest in R&D and in other innovation activities, but mainly in other innovation activities.

Finally, the literature on innovation has stressed the importance of knowledge spillovers in the decision to invest in R&D (Máñez-Castillejo et al., 2006). Spillovers may be understood as ideas borrowed by a firm from the results obtained by another firm (Griliches, 1992). In this paper, we consider two forms of R&D spillovers variables. The first are intra-regional-sectoral R&D spillovers, which capture the knowledge flows that occur in a region within companies operating in the same sector, given that firms are more likely to internalize technological knowledge related to their sector. There is evidence showing that intra-regional-sectorial spillovers have a positive impact on the probability of performing R&D activities (Máñez-Castillejo et al., 2006). The second form of spillovers are inter-regional. Once we have considered the influence of R&D investments of firms from the same sector and region, it is possible that R&D activities performed in nearby regions may influence firms' decision to invest in innovation activities. Thus, we propose the following hypothesis:

> **H5.** Intra-regional-sectorial R&D spillovers and inter-regional R&D spillovers positively influence the decision to invest in R&D and in other innovation activities.

3 | DATA AND METHODOLOGY

3.1 | Data

We use data from the 2015 ENAI,[6] carried out by the National Institute for Statistics and Censuses and the Secretary of Higher Education, Science, Technology, and Innovation for the period 2012–2014. The ENAI is a compulsory survey that follows the directives of the Oslo Manual and contains a representative sample of the innovation activities of 6,275 firms operating in the manufacturing, services, trade, extractive, construction, and utility sectors in Ecuador's 24 provinces. The ENAI aims to provide reliable estimates at the provincial level and by economic sector.[7] Our final sample contains 6,122 observations.[8] Note that, although in Ecuador there is a large share of firms operating in the informal sector, they were not included in the sample. Moreover, ENAI is a firm survey, meaning that it includes multi-establishment firms, some of which may have establishments in different regions.[9]

This study aims to determine regional influence on the decision to invest in R&D and in other innovation activities. To achieve this goal, we define two dichotomous dependent variables. The first one, *R&D*, takes the value 1 for firms that invested in R&D activities (whether internal or external) in at least one of the three years of the survey, and a value of 0 otherwise. The second variable, *Other innovation*, takes the value 1 if the firm invested in at least one of the following activities for the introduction of product and process innovations during at least one of the three survey years: acquisition of machinery and equipment, acquisition of hardware and software, acquisition of unincorporated technology, hiring of consultancy services and technical assistance, engineering and industrial design activities, training of personnel, or market research. Figure 1 shows the regional distribution of the percentage of firms that invested in both innovation activities in Ecuador's 24 provinces. In all regions there are more firms investing in other innovation activities than in R&D.[10] The companies that invest in R&D are concentrated in the mountain range central regions (Pichincha, Santo Domingo, Bolívar and Napo) and in the two largest western coastal regions (Guayas and Manabí). By contrast, the regions with the lower percentage of firms investing in R&D activities are the four Amazonian provinces to the East of the country (Sucumbíos, Orellana, Pastaza and Morona Santiago) and the two provinces in the north (Esmeraldas and El Carchi). Nonetheless, these provinces have a high percentage of firms investing in other innovation activities.

A potential problem with the variable *Other innovation* is that it includes investments in different activities. It might be the case that the impact of regional and individual factors is different for each of its components. For this reason, in the Supplementary Appendix (Table S4) we present the results for the dependent variable *Acquisition*, which only includes investments in the acquisition of machinery, equipment, hardware, software and unincorporated technology for the introduction of new technologies.

Among the internal characteristics of firms that influence the decision to invest in innovation activities, we include the following variables:[11] *Employment*, measured as the logarithm of the average number of employees in the period 2012–2014; *Skilled labour*, measured as the percentage of 2014 employees who held a Bachelor's degree or higher; *Capital investment*, a dichotomous variable that takes the value 1 if the firm invested in fixed capital in at least one of the three years in the survey, and 0 otherwise[12]; *Merger or acquisition*, a dichotomous variable that takes the value 1 if, during the years of the survey, the firm was merged or acquired by another firm; *Foreign group*, a dichotomous variable that takes the value 1 if the firm belonged to a group whose headquarters were located outside Ecuador, and 0 otherwise; and *Exporter*, a dichotomous variable that takes the value 1 if the firm registered exports in at least one of the three years in the survey, and 0 otherwise.

Following Goya et al. (2016), we constructed nine dichotomous sector variables, by technological intensity, using each firm's two-digit code from the International Standard Industrial Classification (ISIC). The Supplementary Appendix shows the different economic activities included in each category (Table S1), the number of firms by sector and province (Table S2), and the estimated final results for the sectoral effects (Table S3).

As will be discussed in the next section, we verify hypothesis H1 by studying the variance explained by random regional effects in a multilevel logit model. Moreover, contextual effects of the specific regional variables will be captured as follows.[13] Hypothesis H2 is evaluated through the variable *Loans to GVA*, which aims to capture the strength of the regional financial system through the volume of credit granted to firms by financial institutions in the region divided by the regional gross value added, both measured in 2012. In Ecuador, bank loans are the second largest financing mechanism for innovation.[14] We use data from the Central Bank of Ecuador for this variable.

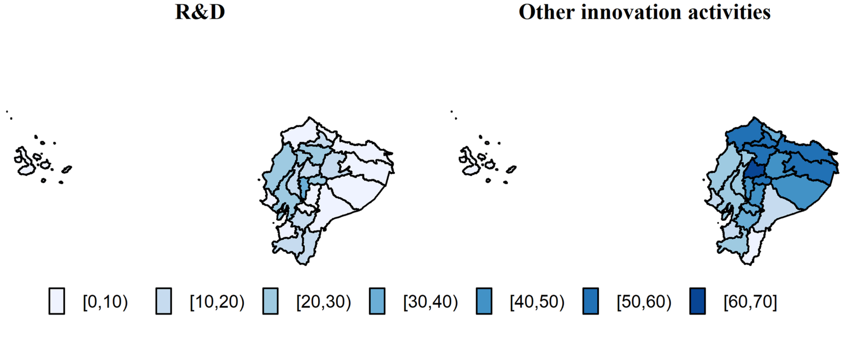

FIGURE 1 Percentage of firms in each province performing innovation activities (6,122 firms)

Hypothesis H3 is evaluated through the variable *Business to total R&D*, defined as the share of regional business expenditure in R&D (BERD) in regional gross expenditure in R&D (GERD), divided by the national share of BERD in total national GERD. This variable seeks to operationalize regional orientation towards knowledge exploitation. A high value for this variable would indicate that the region is more oriented towards knowledge exploitation since most R&D is performed by firms. To construct this variable, we use data from the ENAI and from the 2015 Ecuadorian Science, Technology, and Innovation Activities Survey (ACTI).[15] ACTI is a census on public and private Ecuadorian research institutions that permanently carry out science and technology activities.

We analyse hypothesis H4 through the variable *Co-operating firms*, which uses the ENAI to measure the percentage of firms in each region that established co-operation relationships with external partners to develop product or process innovations in at least one of the following activities during the period 2012–2014: R&D, engineering and design, training, technical support, information, product testing, or financing.

Finally, we analyse hypothesis H5 through the variables *Region-sector R&D spillover* and *Inter-region R&D spillover*, constructed with ENAI data. *Region-sector R&D spillover* is measured as the percentage of firms that perform R&D in the same region and the same three-digit ISIC industry. For region *i*, *Inter-region R&D spillover* ($Inter_i$) is measured as the percentage of firms doing R&D activities in the other 23 *j* regions, weighted by the inverse of the geographical distance from the geographical center of the region to the centers of the other regions, as shown in the following equation:

$$Inter_i = \sum_{j \neq i}^{23} {d_{ij}}^{-1} R\&D_j.$$

There are many other possible ways of measuring inter-regional spillovers (see Woodward et al., 2006). We have estimated the model using different types of spatial lags of innovation variables. The definition above captures a new economic geography approach to innovation, in which the location of each regional system might generate a core-periphery spatial pattern of innovation in the country.[16]

Table 1 shows descriptive statistics for the internal variables of the 6,122 firms included in the sample and for the five regional variables included in the model. Table 2 shows the number of firms by province as well as the regional averages of the firms' internal variables and the values of the regional variables. Note that these tables show gross data, whereas the subsequent models (Table 3) show deviations from the provincial average for the two continuous firm variables, *Employment* (in logarithmic form) and *Skilled labour*; and deviations from the global average, divided by the standard deviation, in the case of the regional variables. These transformations are usual in multilevel models to facilitate convergence of the estimation and interpretation of the results, as well as to reduce multicollinearity.

3.2 | Methodology

We estimate a two-level multilevel logit model, in which level-one data pertains to firms and level-two, to regions. The details are expanded in previous literature on innovation that uses multilevel logit models, reviewed in subsection 2.2. The econometric details of the model are shown in the online Supplementary Appendix.

Using R's lme4 package (Bates et al., 2015), we estimate random intercept models, which capture between context heterogeneity (Duncan et al., 1998; Neira et al., 2018), accounting for regional differences in the dependent variable: location in different regions tends to change the probability of investing in innovation for all the firms in the region. That is what we want to check, and not so much if the effects of specific level-one explanatory variables vary from region to region.[17]

TABLE 1 Descriptive statistics for the sample of firms and the regional data

	Mean	Standard deviation	Median	Minimum	Maximum
Firm variables (6,122 obs.)					
R&D (dichotomous variable)	0.18	0.39	0.00	0.00	1.00
Other innovation (dichotomous)	0.40	0.49	0.00	0.00	1.00
Employment (people)	109.58	339.12	27.00	1.33	1,0142.33
Skilled labour (share)	0.25	0.24	0.17	0.00	1.00
Capital investment (dichotomous)	0.52	0.50	1.00	0.00	1.00
Merger or acquisition (dichotomous)	0.02	0.14	0.00	0.00	1.00
Foreign group (dichotomous)	0.06	0.24	0.00	0.00	1.00
Exporter (dichotomous)	0.14	0.34	0.00	0.00	1.00
Regional variables (24 obs.)					
Loans to GVA (ratio)	131.86	91.84	110.33	6.19	357.50
Business to total R&D (ratio)	0.74	0.73	0.61	0.00	1.92
Co-operating firms (mean of dichotomous firm-level variable)	0.34	0.17	0.33	0.04	0.59
Region-sector R&D spillover (mean of dichotomous firm-level variable)	0.13	0.08	0.11	0.03	0.32
Inter-region R&D spillover (weighted mean of dichotomous firm-level variable)	2.98	0.08	3.00	2.79	3.08

Note: Statistics of the original data. Continuous variables in this table were transformed for the estimation of multilevel models, as explained in the tables with results.

We estimate four models. The *empty* or *null* model (Model 0) uses an intercept only to explain the dependent variable. The level-two residuals of this model are estimates of the regional random effects. With the estimates of the variance of those random effects, it is possible to calculate the share of the variance of the dependent variable that is due to (measured or unmeasured) factors common to the firms located in the same region. That share is called the intra-class correlation coefficient (ICC). When other explanatory variables are added to the model, the ICC is the proportion of the variance of the unexplained part of the dependent variable (residuals) that is due to factors common to the firms located in the same region. As discussed in the Supplementary Appendix, a unique feature of multilevel logit models is that level-one residuals do not exist, because the dependent variable has only two values, 1 or 0. Therefore, the variance of those residuals is assumed to be fixed. That is why some authors do not present the ICC of multilevel logit models. However, even in these models the ICC is a useful indicator of the importance of the regional dimension to innovation.

Once the null model has been estimated, Table 3 shows model 1, adding the internal factors of firm *i* in region *j* (X_ij). In this way, we are somehow controlling for compositional effects: regions might have different propensities to invest in innovation only because they have different types of firms. Then, in model 2, we add the regional variables (Z_j). For reasons of comparability, we keep the same variables in models 1 and 2 for the two dependent variables. However, for the final decision of the preferred models, it is convenient to clean the equations, excluding non-significant variables,[18] as was carried out in model 3, shown in Table 3. For the R&D equation, model 3 also solves a technical issue in model 2: the estimation becomes singular.

Note that the analysis in the context of a developing country constrains the number of innovative firms in the sample. In our sample, 40% of firms invested in *Other innovation*, but only 18% did so in *R&D*. In this latter case, we are studying regional influences in the decision to invest in R&D, so the model requires enough variance to discriminate

TABLE 2 Descriptive statistics by province

Province	Number of firms	R&D	Other innovation	Employment	Skilled labour	Capital investment	Merger or acquisition
Azuay	570	0.12	0.33	79.87	0.25	0.40	0.02
Bolívar	25	0.32	0.40	30.16	0.32	0.64	0.00
Cañar	51	0.04	0.33	62.13	0.28	0.39	0.04
Carchi	60	0.08	0.38	22.68	0.20	0.38	0.02
Chimborazo	143	0.04	0.50	33.38	0.27	0.66	0.03
Cotopaxi	146	0.10	0.61	35.17	0.24	0.64	0.02
El Oro	314	0.06	0.20	45.11	0.20	0.42	0.02
Esmeraldas	97	0.09	0.55	38.13	0.18	0.51	0.00
Galápagos	25	0.08	0.08	29.19	0.16	0.40	0.00
Guayas	1,371	0.22	0.29	163.01	0.27	0.45	0.01
Imbabura	187	0.17	0.55	43.23	0.19	0.66	0.02
Loja	173	0.16	0.23	37.44	0.30	0.45	0.03
Los Ríos	123	0.19	0.28	47.44	0.15	0.42	0.01
Manabí	316	0.20	0.28	97.40	0.22	0.43	0.01
Morona Santiago	24	0.04	0.12	15.57	0.27	0.33	0.00
Napo	26	0.19	0.42	19.71	0.22	0.50	0.00
Orellana	65	0.03	0.54	42.51	0.12	0.71	0.00
Pastaza	28	0.07	0.43	24.74	0.18	0.82	0.00
Pichincha	1,641	0.23	0.55	171.56	0.31	0.62	0.03
Santa Elena	95	0.09	0.18	39.62	0.18	0.43	0.02
Santo Domingo	188	0.20	0.29	31.48	0.12	0.34	0.01
Sucumbíos	62	0.03	0.55	61.86	0.09	0.63	0.00
Tungurahua	366	0.21	0.58	46.17	0.24	0.65	0.01
Zamora Chinchipe	26	0.12	0.08	22.14	0.29	0.42	0.00

Note: Variable *Region-sector R&D spillover* does not appear in the table because its provincial averages are not distinguishable from the provincial averages of R&D.

TABLE 2 Continued

Province	Foreign group	Exporter	Loans to GVA	Business to total R&D	Co-operating firms	Inter-region R&D spillover
Azuay	0.00	0.11	261.7	0.52	0.22	2.98
Bolívar	0.00	0.00	100.0	0.20	0.44	2.79
Cañar	0.00	0.02	51.7	1.92	0.22	3.07
Carchi	0.00	0.03	141.7	0.03	0.35	3.02
Chimborazo	0.01	0.03	133.1	0.03	0.50	3.07
Cotopaxi	0.01	0.06	127.7	0.12	0.59	3.00
El Oro	0.00	0.18	112.7	1.17	0.14	3.05
Esmeraldas	0.02	0.08	63.5	1.92	0.48	3.01
Galápagos	0.00	0.00	53.0	0.03	0.08	3.03
Guayas	0.09	0.21	307.6	1.27	0.27	2.88
Imbabura	0.01	0.04	144.1	0.55	0.53	2.94
Loja	0.00	0.01	146.1	0.19	0.20	2.95
Los Ríos	0.01	0.14	104.2	0.78	0.24	2.92
Manabí	0.01	0.14	177.7	1.09	0.27	2.90
Morona Santiago	0.00	0.00	108.0	0.00	0.04	3.07
Napo	0.00	0.00	92.1	1.92	0.42	2.91
Orellana	0.00	0.00	6.2	0.00	0.49	3.08
Pastaza	0.00	0.04	36.1	0.00	0.46	3.04
Pichincha	0.14	0.18	357.5	1.05	0.51	2.88
Santa Elena	0.03	0.09	60.9	0.00	0.16	3.01
Santo Domingo	0.01	0.08	161.2	1.92	0.30	2.91
Sucumbíos	0.02	0.00	17.0	1.77	0.52	3.07
Tungurahua	0.00	0.04	294.6	0.68	0.59	2.90
Zamora Chinchipe	0.00	0.00	106.3	0.67	0.07	2.99

Note: Variable *Region-sector R&D spillover* does not appear in the table because its provincial averages are not distinguishable from the provincial averages of R&D.

TABLE 3 Multilevel models of firm innovation in Ecuador: 6,122 firms (*i*) in 24 provinces (*j*)

	Model 1				Model 2				Model 3			
	(1) R&D		(2) Other innovation		(3) R&D		(4) Other innovation		(5) R&D		(6) Other innovation	
	Log-Odds	*p*	*Log-Odds*	*p*	*Log-Odds*	*p*	*Log-Odds*	*p*	*Log-Odds*	*p*	*Log-Odds*	*p*
Fixed effects: internal factors (X_{ij})												
(Global intercept)	−1.71	**<0.001**	−1.00	**0.017**	−4.16	**<0.001**	−1.47	**0.001**	−4.01	**<0.001**	−1.44	**0.001**
Log Employment	0.21	**<0.001**	0.18	**<0.001**	0.17	**<0.001**	0.15	**<0.001**	0.18	**<0.001**	0.16	**<0.001**
Skilled labour	0.69	**<0.001**	0.46	**0.002**	0.52	**0.006**	0.41	**0.006**	0.55	**0.003**	0.39	**0.007**
Capital investment	1.62	**<0.001**	2.09	**<0.001**	1.67	**<0.001**	2.05	**<0.001**	1.64	**<0.001**	2.05	**<0.001**
Merger or acquisition	0.55	**0.019**	0.18	0.426	0.73	**0.004**	0.20	0.383	0.70	**0.005**		
Foreign group	−0.55	**<0.001**	−0.15	0.267	−0.69	**<0.001**	−0.17	0.234	−0.66	**<0.001**		
Exporter	0.30	**0.004**	0.16	0.108	0.16	0.173	0.09	0.364				
Fixed effects: provincial factors (Z_j)												
Loans to GVA					0.05	0.503	0.17	**0.027**	0.11	**0.030**	0.17	**0.027**
Business to total R&D					0.05	0.355	0.09	**0.027**	0.14	**0.008**	0.10	**0.026**
Co-operating firms					−0.15	**0.004**	0.57	**<0.001**			0.56	**<0.001**
Region-sector R&D spillover					1.33	**<0.001**	0.52	**<0.001**	1.36	**<0.001**	0.52	**<0.001**
Inter-region R&D spillover					−0.24	**0.026**	0.43	**<0.001**			0.43	**<0.001**
Random effects												
σ^2 (level 1, assumed)	3.29		3.29		3.29		3.29		3.29		3.29	
σ_j^2 (level 2, estimated)	0.44		0.39		0.00		0.02		0.00		0.02	
Intraclass correlation (ICC)	0.12		0.11				0.01		0.00		0.01	
Deviance	4,798.0		6,213.8		3,918.1		5,996.7		3,932.6		5,999.2	

Notes: The two firm-level continuous variables, the log of employment and the % of skilled labour, are considered as deviations to the provincial mean: $X_{ij} - \overline{X}_j$. The Z_j provincial factors are centred and standardized. The models include sector fixed effects, classified by technological intensity (see the Supplementary Appendix). *p*-values lower than 0.05 are in bold.

the effects of specific variables distributed over 24 regions. If the number of firms doing R&D in each region is low, many regional variables tend to overfit the model, so the estimation becomes singular,[19] and the ICC cannot be calculated. Singularity means that the estimated variance of the regional component becomes exactly zero, which might not be a big problem for the estimates. To make sure that the general conclusions were not sensitive to this issue, we have tested different algorithms, producing similar estimates but without a solution to the issue of singularity. For *R&D*, model 2 in Table 3 is singular, while model 3 is not, after simplifying the regional effects, as will be discussed below. As a robustness analysis, Table A5 in the online Appendix shows the estimation of models 2 and 3 in Table 3 using non-mixed models. Using both types of techniques, results of model 2 for R&D show counterintuitive signs for two provincial variables. Deletion of those variables in model 3 also solves the singularity of the multilevel model.

Another concern in multilevel models is the minimum number of level-two units required to have enough dispersion of the data to get unbiased estimates of the individual and regional effects. We have 24 regions and Monte Carlo experiments show that this should be enough for the purposes of the present work (Elff et al., 2021; Stegmueller, 2013). However, Monte Carlo experiments are based on particular assumptions about sample size, while the regional innovation data in a developing country has particular limitations. Our results are conditional to data availability. Only the accumulation of similar empirical studies can help detect robust stylized facts.

A common problem in this methodology is the spatial sorting of firms, which has two implications. First, if compositional effects are not fully captured, the spatial distribution of firms might bias the estimates of the regional effects. Even though multilevel models are designed to deal with unobserved heterogeneity, maybe due to omitted variables (Kim & Frees, 2006), the results for level-two variables are conditional on the regional distribution of possible omitted level-one variables. Depending on data availability and apart from sectoral dummies, López-Bazo and Motellón (2018) controls for 11 firm-level factors, while Aarstad et al. (2019) only for 2. We control for six internal characteristics of the firm. That is probably enough to capture the main compositional effects of each region and avoid strong biases in the estimates of the regional effects.

Second, even if all the relevant level-one variables were considered, there is a remaining issue related to spatial sorting. Cross-sectional multilevel models cannot distinguish causality between characteristics of firms and regions. Some regional variables become endogenous if firm's locational decisions affect regional statistics. With our data, we cannot know if firms with a strong propensity to innovate were attracted to specific regions. We only study the direct effect of being in a particular region once relevant characteristics of the firms in that region are controlled for. This is still a major advantage over traditional single level studies, which ignore the distinction of within-and-between regional differences.

4 | RESULTS AND DISCUSSION

Table 3 presents the results on the determinants of the decision to invest in R&D and in other innovation activities.[20] The first two columns show the results of the models that include composition effects (model 1). The next two columns show the estimations of model 2, in which contextual regional effects are also incorporated. The last columns show a cleaning of model 2, to derive our preferred models, in columns (5) and (6).

The null models (model 0), without explanatory variables, are not included in Table 3. As discussed in subsection 3.2 and in the Supplementary Appendix, we use the ICC to get a general idea of the importance of regional factors in firms' propensity to invest in innovation. The ICC of the null models shows that differences among regions explain 10% and 13% of the observed variation in the propensity to invest in R&D and in other innovation activities, respectively. This result supports hypothesis H1: some common factors affect the decision of firms in the same region to invest in both types of innovation activities. However, the null model does not allow us to distinguish whether geographical differences are due to differences between firms in different regions. To control for this, columns 1 and 2 (model 1) in Table 3 show the results of models that include both individual firm characteristics and sectoral dummies (see Table S3 in the Appendix for these sectoral dummies).

Results of the firm-level variables indicate that the log of *Employment* is positively related to both investment decisions. This result is not surprising, since the size of the firm provides advantages related to setting up innovation activities (Cohen, 1995). Another variable positively associated to both decisions is employees' qualification level, as human capital is the fundamental resource for achieving greater innovative performance (Felin & Hesterly, 2007). Investment in fixed capital is positively related to both investment decisions. This result agrees with findings by Toivanen and Stoneman (1998), who argue that, as a firm extends its capability through investment in fixed capital, the firm's own installation process and use of capital provides it with valuable knowledge for setting up innovation activities.

Three individual characteristics are associated with the decision to invest in R&D but are not found to be significant to the decision to invest in other innovation activities. The first is *Merger or acquisition* which positively affects the decision to invest in R&D. The second is belonging to a *Foreign group*, which has a negative effect on the decision to invest in R&D. Although foreign firms usually have more resources to innovate, Chaminade et al. (2009) indicate that foreign firms usually locate routine activities in developing countries due to the weaknesses of their innovation systems. Therefore, it is not surprising that these companies are less likely to invest in R&D. Finally, the results suggest that exporting motivates firms to invest in R&D. Nevertheless, this variable is no longer significant when contextual factors are included (model 2). In particular, *Exporter* is not significant once the *Region-sector R&D spillover* is included, probably due to common sectoral attributes between exporters.

Columns 3 and 4 (model 2) show the results when the five regional variables are added to the equations. However, as pointed in subsection 3.2, the estimation of the R&D equation in column (3) becomes singular. In columns 5 and 6 (model 3) we present a clean version of model 2, which exclude non-significant firm-level variables from both equations and *Co-operating firms* and *Inter-Region R&D spillover* from the R&D equation, which have counterintuitive signs in model 2. Singularity is solved by excluding *Co-operating firms* and, once this variable is excluded, *Inter-Region R&D spillover* is no longer significant. Additional robustness analysis using non-mixed models, shown in Table S5 of the online Appendix, using clustered standard errors, confirm our preferred model 3.

Results from model 3 indicate that *Loans to GVA* is positively associated with both investment decisions. Thus, although most developing country firms tend to finance their innovation activities with internal resources, the regional availability of external funds also influences firms' decisions to invest in innovation. Additionally, results from model 3 in Table S6 of the online Appendix show that the odds ratio of *Loans to GVA* is slightly greater for the decision to invest in other innovation activities. Therefore, although hypothesis H2 is met, the difference in odds ratios is very small. So, we did not find clear evidence on the strength of the financial system further influencing the decision to invest in other innovation activities.

The regional orientation towards knowledge exploitation (*Business to total R&D*) is also positively associated with both R&D and other innovation activities. Thus, Ecuadorian firms are more likely to invest in innovation activities when they are located in regions where most R&D is made by firms. This result confirms hypothesis H3. Model 3 also indicates that the regional percentage of firms co-operating in innovation activities is positively associated with the decision to invest in other innovation activities. We cannot confirm, however, hypothesis H4, as the inclusion of *Co-operating firms* in the R&D equation results in a counterintuitive negative sign and a singular estimation. Column (6) in Table 3 confirms a positive association between *Other innovation* and this regional characteristic, which is not surprising. Co-operative relationships in Ecuador seek primarily to obtain technological information and set up training activities and technical support for employees rather than science-based R&D (Fernández-Sastre & Vaca-Vera, 2017). These activities are complementary to investments in other innovation activities, since the acquisition of technologies for innovation often requires training, technical support, and information on complementary technologies.

Finally, results for the R&D spillover variables indicate that *Region-sector R&D spillover* effects have a strong influence on both investment decisions, although, as expected, its impact is greater for the decision to invest in R&D. This confirms that geographical and technological proximity facilitate the flow of knowledge and stimulate innovation activities. By contrast, in column (3) of Table 3, the variable *Inter-region R&D spillover*, which captures the location of each RIS in the National Innovation System, exhibits a counterintuitive negative sign for *R&D*, which are the innovation activities more affected by *Region-sector R&D spillover*. This is consistent with specialized knowledge spillovers in the same region and sector influencing the investment decisions, and not so much general knowledge externalities across the country. Conversely, each region's location seems to affect the flow of the kinds of knowledge and skills relevant for the decision to invest in *Other innovation*. Therefore, results in columns (5) and (6) confirm our hypothesis H5 about the positive role of intra-regional-sectorial and inter-regional R&D spillovers in the decision to invest in innovation activities, except for *Inter-region R&D spillover* effects on the decision to invest in R&D.

The online Supplementary Appendix shows a robustness analysis for the variable *Other innovation*. As pointed in subsection 3.1, this variable includes investments in many different activities. Therefore, Table S4 of the Appendix shows the estimates for the decision to invest in a particular set of those activities, the *Acquisition* of machinery, equipment, hardware, software, and unincorporated technology. The results are very similar to those of *Other innovation*, with minor differences. In particular, *Loans to GVA* is no longer significant for the dependent variable *Acquisition*.

As a robustness test, Table S7 in the Supplementary Appendix shows the models in columns (5) and (6) of Table 3 distinguishing between *Small* and *Large* firms. Results indicate two main regional differences: *Loans to GVA* is only significantly associated with the decision to invest in innovation activities for small firms and *Business to total R&D* is only associated with the decision to invest in R&D of small firms and with the decision to invest in other innovation activities for large firms. Additionally, the tables and figure in Section 8 of the Supplementary Appendix show post-estimation tests related to the normality and spatial autocorrelation of level-two residuals for the models in columns (5) and (6) in Table 3.

The Supplementary Appendix provides additional information about post-estimation tests of our preferred models, in columns (5) and (6) in Table 3, focusing on the spatial distribution of the estimated level-two residuals.

Finally, regarding the influence of RIS factors, Table S6 in the online Appendix indicates that the decision to invest in R&D is mainly motivated by *Region-sector R&D spillovers*, while *Loans to GVA* and *Business to total R&D* have similar odds ratios. For the decision to invest in other innovation activities, the results indicate that, although there are some differences in the odds ratios of the regional variables affecting the decision to invest in other innovation activities, their influence is quite similar. For this decision there is no regional factor that clearly stands out above the others.

In summary, the average ICC of the two null models for *R&D* and *Other innovation* is 11.3%, and remains almost the same when internal factors are added to the equation in Model 1 (11.1%). The average ICC of the models in columns (5) and (6) in Table 3, for Model 3 is 0.3%, revealing that our regional variables have been able to capture virtually all the regional component in the decision to invest in innovation.

5 | CONCLUSIONS

Using data from the 2015 Ecuadorian Innovation Survey and multilevel logit models, this paper contributes to empirical studies on regional influence on innovation by analysing the extent to which firms' decisions to invest in R&D and in other innovation activities are conditioned by the province in which they are located. The study also evaluates five hypotheses on the influence of five characteristics of the regional innovation systems (RISs) that might help explain the varying behavior of firms located in different regions.

This research paper's results are consistent with the regional innovation systems perspective, as they indicate that both investment decisions (in R&D and other innovation activities) are conditioned by geographical location, even after controlling for the individual and sectorial characteristics of the firms. Specifically, our results indicate that around 10% of the observed dispersion in the propensity to invest in R&D is due to regional differences, as is around 13% of the dispersion observed in the propensity to invest in other innovation activities.

Our results also indicate that the decision to invest in R&D activities is positively affected by the regional volume of loans to firms, the orientation towards knowledge exploitation and intra-regional-sectoral R&D spillovers. In addition to these regional determinants, the decision to invest in other innovation activities is also positively influenced by the regional level of co-operation in innovation activities and inter-regional spillovers. Taken together, these regional variables can explain virtually all the detected regional component of our dependent variables.

This study has some limitations. As any other cross-sectional multilevel study, we just examine the direct influence of geographical characteristics on the decision to innovate, but we cannot take into account that innovative-prone firms may locate in regions with certain external conditions. This may lead to confound the estimate of the effect of regional factors. Additionally, Ecuadorian data may be considered high quality data in the context of developing countries, however, it presents some limitations: the informal sector was not included, there are few companies that invest in R&D, there were few observations in some regions, large companies were overrepresented in the sample. From a methodological standpoint, although we have done a large number of empirical tests, we have focused on some possible contextual variables, and ignored other possible channels of causality.

The evidence shown in this paper has implications for innovation policies in developing countries. It indicates that region-level policies can have a significant influence in motivating firms to become involved in innovation activities. Specifically, policies that aim to strengthen regional lending capacity can promote investments in R&D activities. Further, policies that promote technological co-operation will motivate investments in other innovation activities. Our results also argue in favour of the benefits of choosing a systemic approach when implementing innovation policies. In less advanced countries, development of the business capabilities needed for innovation is closely tied to restructuring of the institutional context, the legal environment and construction and modernization of infrastructures that generate the knowledge firms require.

Finally, this study opens future lines of research on the influence of RISs in firms' innovation effort and performance through multilevel methodologies. More multilevel studies are needed on the decision to invest in innovation in developing countries, comparing the role of the RISs and the effects of different variables. We propose that future studies maintain the structure of reporting results for models 0, 1, 2 and 3, as we have done here, to increase the comparability between results of the effects of location on business innovation.

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ENDNOTES

[1] We use "region" to refer to the 24 provinces of Ecuador, which are second-order administrative units.

[2] Innovative performance refers to the introduction of new products and processes.

[3] Some previous papers have analyzed regional effects in samples that include several developing countries (Barasa et al., 2017; Khiaria & Ben Rejeb, 2015; Schmutzler & Lorenz, 2018; Srholec, 2011). This is not necessarily an advantage. In some cases, the decision to group several countries in the sample is motivated by insufficient regional units to perform separate studies by country. Variance among countries is usually excluded through dummy variables, ignoring the fact that variables of the regional environment also have intra-country correlation. It is usually assumed that the effects of factors inside and outside the firm are the same in all countries.

[4] These activities are the following: acquisition of machinery, equipment, hardware and software; acquisition of unincorporated technology; hiring of consultancies and technical support; engineering and industrial design activities; training of personnel; and market studies.

[5] According to the ENAI, 67% of the innovation projects were financed with firms' own resources.

[6] http://www.ecuadorencifras.gob.ec/encuesta-nacional-de-actividades-de-ciencia-tecnologia-e-innovacion-acti/

[7] ENAI's methodological document, Table 2 shows the number of firms included in the sample by province: https://www.ecuadorencifras.gob.ec/documentos/web-inec/Estadisticas_Economicas/Ciencia_Tecnologia-ACTI/2012-2014/Innovacion/MetodologIa%20INN%202015.pdf

[8] See Section 1 in the Supplementary Appendix for a list of removed observations.

[9] 82.4% of the firms in our sample have a unique establishment. Repeating the analysis shown in Table 3 below only for those firms produces very similar results to those shown in Table 3. Results are available upon request.

[10] The only exception is the southern province of Zamora Chinchipe, which is not characterized by its competitive dynamism. Our sample only contains 26 firms from this province.

[11] In addition to the internal characteristics described, we initially included the following variables: *labor productivity*, *age and market share*. They showed no significance in the subsequent regressions.

[12] Investment in fixed capital may include expenses for the replacement of machinery, acquisition of new equipment, or the implementation of an innovation. Thus, there could be some mechanical correlation with the *Other innovation* variable. Table A4 in the online appendix shows the estimates of the final model excluding *Capital investment*. The results are quite robust. The only difference is that Loans to GVA is no longer significant.

[13] We initially considered other regional indicators, such as the following: *Gross value added* per capita, *Regional R&D investment divided by Gross value added, Regional mean of Skilled labor, Population with a university degree divided by population over 15 years of age*, *High school student performance index, Number of universities divided by the total number of universities in Ecuador*, *Percentage of industrial employment*, *Regional exports divided by regional total sales*, *Percentage of firms participating in innovation support programs*. We do not present these results because they were not significant. However, as a robustness analysis, Table A6 in the online Appendix shows additional results when regional Gross Value Added per capita is included in the model.

[14] According to the ENAI, 17% of the innovation projects of Ecuadorian firms were financed with bank loans.

[15] https://www.ecuadorencifras.gob.ec/encuesta-nacional-de-actividades-de-ciencia-tecnologia-e-innovacion-acti/

[16] Note that the R&D spillovers variables are built using observations available from each region. Although the ENAI is representative at the provincial level, some provinces have few observations. Thus, there might be a problem of measurement error with these indicators.

[17] The latter is called between-individual heterogeneity and can be modelled through random slopes or cross-level interactions. Even though they are not an operational goal in this paper, we have tested interactions between several variables, and have not found them to be significant.

[18] Estimation results are generally not sensitive to the inclusion of non-significant level-one variables. However, they may be very sensitive to the inclusion of non-significant level-two variables, given that their values are constant for all the firms in the same region (zero within-region variance). Therefore, incorporating many level-2 variables can easily create overfitting or multicollinearity.

[19] See http://bbolker.github.io/mixedmodels-misc/glmmFAQ.html#troubleshooting.

[20] As in other papers in the literature, Table 3 shows the estimated coefficients, which make obvious the variables with a negative impact. Table A6 in the online Appendix shows the odds ratios discussed in the methodological section of that appendix, which are more useful to compare the effect size of the variables.

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Resumen. Este es el primer estudio que utiliza la modelización multinivel para analizar la influencia regional en la decisión de invertir en las actividades de innovación de las empresas de un solo país en desarrollo, Ecuador. Los resultados indican que la decisión de invertir en I+D y en otras actividades de innovación está condicionada por la región en la que se encuentra la empresa. El volumen de préstamos regionales, la orientación hacia la explotación del conocimiento y los *spillovers* de la I+D intrarregional-sectorial están asociados positivamente con ambos tipos de actividades de innovación, mientras que los niveles regionales de cooperación y los efectos indirectos de la I+D inter-regional sólo están asociados positivamente con la probabilidad de invertir en otras actividades de innovación.

抄録: 本稿は、単一の開発途上国であるエクアドルにおける企業のイノベーション活動への投資の意思決定に対する地域の影響を、マルチレベルモデリングを用いて分析した最初の研究報告である。結果から、研究開発及びその他のイノベーション活動への投資の意思決定は、どの地域に企業が立地しているかに左右されることが示される。地域の融資額、知識活用指向、及び地域内の研究開発スピルオーバーは、研究開発とその他のイノベーション活動の両方と正の関連性があるが、地域レベルの業務提携や地域間の研究開発スピルオーバーは、その他のイノベーション活動への投資の可能性と正の関連性があるだけである。