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INNOVATION STRATEGY DECISION: A DISCUSSION OF COMPLEMENTARY BETWEEN TECHNOLOGICAL AND NON-TECHNOLOGICAL INNOVATIONS

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CONCEPCION

A mi Hija, el mejor regalo de Dios,
mi partner,
mi compañera,
mi cable a tierra.
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ABSTRACT

There is an extensive theoretical and empirical discussion regarding the linear relationship between R&D expenditure and innovation. However, the innovation-decision is not dichotomous since it implies the choice of a combination of technological and non-technological innovation options. Similarly, not only does internal R&D spending allow firms to innovate, but so-called non-R&D activities also allow firms to develop innovations. In this thesis we analyze two theoretical currents found in the innovation literature, innovation strategy and innovation complementarity, to discuss and show which of them allows us to better explain the innovation-decision of firms. We also analyze the effect that internal and external characteristics of firms have on their preferences for the types of R&D and non-R&D activities for the development of innovatioNS

INTRODUCTION

Innovation in firms has become a source of competitive advantage. The literature now shows that firms that develop innovations perform better than those that do not, and that there is necessarily a linear relationship between R&D spending and innovation. However, these assertions have been developed mainly for discussions of dichotomous innovation between innovating and not innovating, with emphasis on technological innovations and with internal and external R&D spending as the main determinant.

Today, when firms decide to innovate, they can do so based on a combination of technological (product and process) and non-technological (organizational and marketing) innovations. And they can do so from a vision of innovation strategy (where they choose some possible combination among the 4 available types) or by means of complementarity of innovations (where it has been discussed that non-technological innovations are an input for technological innovations). In addition, and recognizing the limitations of medium and small firms in accessing financing for R&D expenditure, the possibility of developing non R&D activities allows firms to innovate, and thus broadens the options beyond just internal and external R&D.

We work with innovation survey data from Chile, Ecuador, Colombia and Spain and using multinomial logit, multivariate probit and discrete-continuous extreme value multiple models we analyze the effect of internal and external firm characteristics on firms' innovation decision and their spending between R&D and non-R&D activities. Our main results show there are differences between firm sizes, human capital and the relevance of total spending various R&D activities on innovation decisions. We can also say that the best way to explain the firm's innovation decision is by the complementarity of innovations rather than by the strategy decision, and there is a high correlation between organizational and process innovation. In relation to the discussion of expenditure, we see that in Latin American countries preferences are for non R&D activities compared to Spain where preferences support internal and external R&D activities.

In chapter 1 we discuss how the internal and external characteristics of the firm affect the decision of an innovation strategy for the particular case of Chile, while in chapter 2 we discuss which is the best model to describe the innovation decision of a firm between strategy and complementarity. We close in chapter 3 with the discussion of the decision regarding the expenditure between R&D and non-R&D activities of the firms.

CHAPTER 1: FIRM´S HETEROGENEITY AND INNOVATION STRATEGY DECISIONS

2.1 Abstract

Research on innovation strategy, which focuses on what type of innovation that firms decide to implement, has primarily focused on dichotomic (yes or no) options and is mostly based on the determinants of technological (product and process) innovations. This paper extends the study of innovation strategy to no-technological innovations (organizational and marketing) and opens an understudied form of innovation strategy encompassing all possible combinations of innovative alternatives for the firm. We argue that implementing an innovation strategy must encompass all possible combinations that allow firms to create and capture value. We test our propositions with data from 5,876 firms from the 2015-2016 panel from the Chilean Innovation Survey. We use a multinomial logit model to describe how a firm's characteristics affect the choice of an innovation strategy. Furthermore, we address the potential existence of endogeneity in innovation studies when research and development (R&D) is used as an explanatory variable. The results show that different firms's characteristics have heterogeneous effects on firm innovation strategy. Additionally, once corrected for endogeneity, the results show that the variables measuring firm size and group membership are no longer significant in determining different innovation strategies. We discuss the theoretical and practical implications of our findings and relate them to current research on innovation strategy.

Keywords: innovation strategy, heterogeneous firms, multinomial logit estimation.

JEL classification: C35, M21, O30, O31,

2.2 Introduction

Scholars have long demonstrated the role of innovation in the firm's competitive advantage (Abdu and Jibir, 2018; Carboni and Russu, 2018; Godin, 2008; Tavassoli and Karlsson, 2016). To engage in innovative activities, firms must develop an innovation strategy, which can be understood as to how organizations create and capture value and, most importantly, which innovations the firm decide to implement (Pisano, 2015). Most of the research in this area has focused on dichotomic decisions in which an organization decides whether to innovate on each of the possible available alternatives (Barbosa et al., 2014; Divisekera and Nguyen, 2018; Teixeira and Bezerra, 2016). However, little is known about the determinants that make firms choose to engage in multiple types of innovation at the same time, which is known as a complex innovation strategy (Tavassoli and Karlsson, 2016).

A large body of research shows the antecedents of innovation at the organization, industry, and country levels (Damanpour, 2014). Additionally, most of the literature on this subject has prioritized the study of antecedents and consequences of technological innovations (Birkinshaw et al., 2008; Volberda et al., 2013), with a focus on the manufacturing industry (Khosravi et al., 2019; Pippel, 2014). Nevertheless, early research in this area has noted the potential contributions of nontechnological innovations (Arrow, 1962; Chandler, 1962; Evan, 1966; Kahn and Candi, 2021; Szczygielski et al., 2017; Walker et al., 2015) showing that technological and nontechnological innovations positively impact firm performance.

The absence of robust literature on the coexistence of technological (product and process) and nontechnological (organizational and marketing) innovations has limited our understanding of the determinants of innovation in situations where organizations must select among a diverse pool of innovative combinations. We seek to understand how firms innovate and choose among four types of innovations: 1) processes, 2) products, 3) organization, and 4) marketing. We propose that extending the study of innovation strategy to more complex strategies encompassing nontechnological innovations is not only coherent but also creates a theoretical bridge between the innovation strategy literature and other areas of research on, especially nontechnological types of innovation.

The innovation decisions of firms are highly heterogeneous (Cecere, 2013; Fazlıoğlu et al., 2019; Tavassoli and Karlsson, 2016) even among firms of the same size or the same industrial sector. Therefore, to comprehend innovation decisions, it is relevant to understand the determinants of how firms choose a combination of available innovation alternatives (Anzola-Román et al., 2018; Černe et al., 2016; Khosravi et al., 2019; Mothe and Nguyen-Thi, 2012). Examining decisions between different types of innovation or strategies allows us to identify behavioral differences that cannot be highlighted when only focusing on innovative and non-innovative firms (Amélia Castro Teixeira and Cristina

Bezerra dos Santos, 2016; Barbosa et al., 2014; Divisekera and Nguyen, 2018; Zemplinerová and Hromádková, 2012).

This study aims to make three primary contributions. First, previous studies have primarily examined how firms can benefit from implementing innovations mostly as independent events (Adeyeye et al., 2015). In contrast, this study contributes to the innovation literature by going beyond the dichotomic "yes/no" decision to innovate, which is pervasive in the literature (Bhattacharya and Bloch, 2004), and accounts for the fact that innovation decisions are characterized by a decision process involving a portfolio of different innovation strategies. We follow Karlsson and Tavassoli (2016) proposal to analyze the firm's decision within a series of innovation strategies instead of considering the four types of innovation as independent decisions. This paper analyzes innovation decision as a selection among 16 possible innovation strategies that arise from combining the four types of innovation plus the alternative not to innovate. We use data from the Chilean innovation survey in its latest available version (2017).

Second, we theorize that innovation combinations made by firms create value to different stakeholders, such as clients, suppliers, collaborators, and the communities in which the organizations exist. We include four types of innovations: technological innovation in products and processes and nontechnological innovations in organizations and marketing. Studying and comparing these two pairs of innovation types will improve our understanding of different organizational characteristics related to specific combinations of innovative strategies.

Third, unlike similar previous studies that consider several innovative strategies, we address the endogeneity problem in this study. Du et al. (2007), Karlsson and Tavassoli (2016), Carboni and Russu (2018), and Anzola-Román et al. (2018) do not control for the possible existence of endogeneity. Unfortunately, endogeneity might be a problem when research and development (R&D) expenditure is used as an explanatory variable in the model (Cassiman and Veugelers, 2002). To correct endogeneity, we followed Crespi and Zuniga (2012) by using the lag of skilled employees and exports as instrumental variables (IVs). Patents, information sources, and cooperation sources as IVs and other exogenous variables are used to predict the value of R&D expenditure per capita, which is included as an explanatory variable in the final regression. We used a multinomial logit model to estimate innovation decisions. In this model, a firm chooses one of several innovation strategies. Innovation strategies correspond to all possible mutually exclusive options that combine product, process, organizational, and marketing innovations (Damanpour and Aravind, 2011; Du et al., 2007).

In the next section, we define the different types of innovations included in this study, differentiate between simple and complex types of innovative strategies, and provide theoretical justifications for the relationship between a firm's characteristics and its innovative activities. This is followed by a description of the data and sample, the analytical method, and the statistical results. The results reveal heterogeneous effects of innovation strategy on the decision to innovate. The most relevant finding is that firms' R&D spending is significant for all kinds of strategies and, in some cases, is more relevant than employees' training level. When a firm opts for a strategy that includes organizational innovation, human capital is statistically significant and positive.

Additionally, medium and large firms tend to choose strategies that combine two or more alternatives compared to small firms. After correcting for endogeneity, the variables measuring firm size and group membership are no longer significant in determining different innovation strategies. We discuss the implications of our study for research on the relationship between innovation strategies and types of innovation. The paper ends by listing the study's limitations and our concluding remarks.

2.3 Literature Review

2.3.1 Innovation Tipology

Innovation can be classified under different dimensions such as: technological versus nontechnological; architecture versus modular; incremental versus radical; and enhancing capabilities versus destructive capabilities (Schilling, 2012). Likewise, there are different innovation processes, such as the generation, diffusion, and adoption of innovation. By distinguishing between technological and nontechnological innovations, scholars have a better understanding of the different antecedents and consequences of innovation at the organization level. Product and process innovations are categorized as technological innovations while organizational and marketing innovations are categorized as nontechnological innovations (OECD, 2005). Product innovation is the introduction of a new product or service to meet a user's needs while process innovation is the introduction of new elements to the production process or service operation (Damanpour, 2010; Utterback, 1994). We define organizational innovation as the introduction of new programs and practices pertaining to new approaches in devising strategy, structure, administrative systems, managerial processes, and organizing relations with other enterprises (Birkinshaw et al., 2008; Damanpour, 2017; OECD, 2005). Marketing innovation is defined as improvements in product design, placement, promotion, or pricing (Deshpandé et al., 1993; OECD, 2005).

2.3.2 Simple versus Complex Innovation Strategies

The literature on analyzing the differences between innovative and noninnovative firms in different contexts (e.g., countries, industries) and defining a set of variables that affect the propensity to innovate is extensive (Abdu and Jibir, 2018; Ayalew et al., 2019; Bhattacharya and Bloch, 2004; Du et al., 2007). However, more recent studies have recognized that firms can choose among four types of innovation: product, process, organizational, and marketing. Firms can also choose a combination of these innovation strategies (Agwu et al., 2019; Carboni and Russu, 2018; Karlsson and Tavassoli, 2016; Tavassoli and Karlsson, 2016).

Innovation decisions can be characterized as a tree decision in which firms first decide whether to innovate. Conditional on the decision to innovate, firms face several innovation strategies and choose the one that best fits their internal capacities and environment (Agwu et al., 2019). The literature shows a broad and more extended discussion on firms' decisions to innovate, emphasizing technological innovations (product, process, or both), and a recent, growing debate on the relevance of the complementarity of innovation decisions. The most relevant aspect of this analysis is that all types of innovations are under consideration as a possible decision for a firm (Agwu et al., 2019; Bartoloni and Baussola, 2018; García-Piqueres et al., 2020; Lee et al., 2019).

The literature has extensively discussed the binary innovation decision of firms and their implications for performance and technological innovations. For instance, out of 70 papers reviewed, 40% evaluate the effect of innovation on performance (Álvarez et al., 2015; Dachs et al., 2017; Evangelista and Vezzani, 2010; Falk, 2015; Geldes et al., 2017; Hashi and Stojčić, 2013; Hervas-Oliver et al., 2017; Mothe and Nguyen-Thi, 2012; Mothe and Thi, 2010; Pino et al., 2016; Szczygielski et al., 2017; Tavassoli and Karlsson, 2016). Only 14% of papers analyzed nontechnological innovation decisions (Egbetokun et al., 2015; Mothe and Nguyen-Thi, 2013; Robin and Schubert, 2013; Silva et al., 2013). Furthermore, only 5% analyzed the four types of innovation but as separate decisions (Agwu et al., 2019; Carvalho et al., 2013; García-Piqueres et al., 2020). Only one paper considers a more comprehensive approach to asset innovation strategies (Karlsson and Tavassoli, 2016).

Karlsson and Tavassoli (2016) defined 16 innovation strategies derived from the possible combinations of the four types, plus the option of no innovation. Depending on the combination, they defined simple strategies as those that include only one kind of innovation, low- and medium-complexity strategies, and complex strategies as those that simultaneously involve all four strategies. They used a multinomial logit model to determine how firms' characteristics and environment affect innovation decisions.

A pervasive theoretical variable included in the literature to explain innovation is firms' innovation effort, measured as spending on R&D activities. Scholars have shown that R&D activities affect firms' innovation decisions and performance (Abdu and Jibir, 2018; Adeyeye et al., 2015; Álvarez et al., 2015; Anzola-Román et al., 2018; Baum et al., 2019; Camisón and Villar-López, 2014). The literature on innovation has analyzed these relationships using the structural model proposed by Cépon, Diguet, and Piresse (CMD model). This model allows us to link the relationship between innovation activities, innovation outcomes, and their effects on firms' productivity by employing several equations. For instance, Crespi and Zuniga (2012) tested the relationship between technological innovations and Latin American firms' productivity, showing a positive relationship between R&D investment, innovation decisions, and productivity. Aboal and Garda (2016) found that firm size is a determinant in the Uruguayan manufacturing sector but not in the services sector. In particular, firm size, cooperation activities, and public financing affect technological and nontechnological innovation decisions. In a modified version of the CDM model, Muinelo-Gallo (2017) used three categories of R&D intensity and found a positive effect of R&D activities on product and process innovations.

The decision to innovate has been linked to other relevant variables, including firm size and competition level (Acs and Audretsch, 1988). Schumpeter (1934) argued that small firms have a greater propensity to innovate since they are more flexible to change than large firms and can obtain more benefits in small markets. Furthermore, innovation is necessary for firms must differentiate themselves in competitive markets to achieve better performance (Arrow, 1962). However, since the development of innovation implies financing, firms with market power tend to be more innovative because they can access funding (Schumpeter, 2016). Therefore, the discussion of innovation starts with considering the effect of firm size on innovation. Acs and Audretsch (1988) indicated that industries with larger firms tend to be more innovative and that lower industrial concentration levels are associated with greater innovative activity. Schubert (2010) showed that larger market share has a negative impact when firms decide only on technological innovation but has a positive impact when firms combine technological and nontechnological innovation. Furthermore, Shukla (2019) showed that high industrial concentration has a negative and significant effect on R&D intensity at the firm level.

Furthermore, the innovation processes that firms develop involve the generation of knowledge, which occurs during their R&D activities or through the firm's ability to acquire knowledge from their environment (Milan et al., 2020). Thus, human capital is relevant to learning from others and allowing ideas to flow within the firm. The literature has that human capital in the firm (defined as the level of training of employees) has a positive effect on the decision to innovate (Capozza and Divella, 2018; Protogerou et al., 2017; Ramírez et al., 2019) on R&D activities (Adeyeye et al., 2015).

2.4 Data and Methodology

2.4.1 Data and Sample

We empirically examined our hypotheses using data from the Chilean Innovation Survey, which is administered by the Ministry of Economy. Chile is the only country in South America that is member of the Organisation for Economic Co-operation and Development (OECD). The design and methodology of the Chilean Innovation Survey followed the guidelines suggested by the OECD's Oslo Manual (2005), and the survey is similar to the Eurostat Community Innovation Survey (CIS). The Chilean Innovation Survey has been implemented every two years since 1995. Thus far, the results from nine panels have been published based on samples covering 95% of statistical representativeness regarding the distribution of companies by region (national representativeness), economic sector (economic activity representativeness), and the size of companies according to annual sales defined by the Ministry of Economy. This paper used information from the latest available version (2015-2016) of the Chilean Innovation Survey developed by the Ministry of Economy, Development and Tourism. This survey allows us to study each of the four types of innovations upon which firms can decide. The survey data also provide information on firm characteristics and various activities related to innovation. The survey included 5,876 firms, of which 1,380 (24%) developed at least one type of innovation. By type of innovation, 44% of firms innovated in products, 64% in processes, 57% in organization, and 44% in marketing. Importantly, many firms chose a strategy that involved more than one innovation alternative. Table 1 shows the distribution of firms according to type of innovation. Only 38% of the innovating firms decided on a single type of innovation, typically technological. In comparison, 62% of the firms decided on an innovation strategy that involved two or more types of innovations. Only 7% of firms had technological innovation strategies that combined products and processes, while 5% took a nontechnological approach that combined organizational and marketing.

2.4.2 Dependent variable

The dependent variable is the firm's innovation strategy within the 15 possible options presented in Table 1.1 plus the no innovation options. Therefore, there are, $j = 1, .., 16$ alternatives. The dependent variable y_i takes the value $y_i = 1$ if the firm chose the ith alternative and $y_i = 0$ otherwise. Our objective is to analyze firms' choice of innovation strategy or decision of not innovating among the 15 possible combinations of product, process, organizational, and marketing innovation.

Table 1.1: Innovation Strategies.

Strategy	Frequency	%	Strategy	Frequency	%
Only Technological			Both technological and nontechnological		
Product	88	6,3%	Product + organizational	34	2,5%
Process	189	13,7%	Product + marketing	20	1,4%
Product + Process	106	7,7%	Process + organizational	109	7,9%
			Process + marketing	40	2,9%
Only non-technological			Product + organizational + marketing	35	2,5%
Organizational	132	9,6%	Process + organizarional + marketing	109	7,9%
Marketing	113	8,2%	Product + process + organizational	110	7,9%
Organizational + marketing	80	5,8%	Product + process + marketing	32	2,3%
			Product + process + organizational + marketing	183	13,2%
Innovator	1.380		No innovators	4496	

2.4.3 Explanatory variables

To determine the relevant explanatory variables, we followed previous literature on the determinants of the propensity to innovate. Table 1.2 presents the descriptive statistics of these explanatory variables.

The first group of variables are firm characteristics and include the following. **Age** represents the firm's age and describes the learning characteristics or accumulation of knowledge over time. It is a proxy of the learning process and an indication of life cycle (Agwu et al., 2019; Coad et al., 2016; Cucculelli and Peruzzi, 2020; Du et al., 2007). Age is the difference between the survey's year of application and the firm's date of creation. **Qualified employees** measures the firm's absorptive capacity, which represents the possibility of acquiring knowledge for the development of innovations (Capozza and Divella, 2018; Carboni and Russu, 2018; Du et al., 2007; Ramírez et al., 2019; Tavassoli and Karlsson, 2015). It is quantified as the percentage of employees with tertiary or higher education out of the firm's total number of employees. **Size of the firm** (number of employees) measures access to resources and possibilities for developing economies of scale or scope (Agwu et al., 2019; Álvarez et al., 2011; Anzola-Román et al., 2018; Cassiman and Veugelers, 2002; Evangelista and Vezzani, 2010; Mardones and Zapata, 2019; Martínez-Ros and Labeaga, 2002). We split this variable into four categories to differentiate firms. Microfirms have fewer than 10 employees, small firms have between 10 and 26 employees, medium-sized firms have between 25 and 200 employees, and large firms have more than 200 employees. We differentiated by firm size to analyze differences that occur between firms when choosing an innovation strategy and include this variable because the literature traditionally uses only one measure of size. Finally, we used **R&D expenditure** as the per capita expenditure of firms on these activities. Firms' knowledge development for innovation is a product of the effort invested into their internal and external R&D activities (Aboal and Garda, 2016; Álvarez et al., 2011; Crespi and Zuniga, 2012; Du et al., 2007). We measured this effort by using the total amount that firms spend on R&D activities.

The second group of variables included in the analysis represent the **firm's environment**. Firms can access information and know to make innovation decisions based on their environment.

Table 1.2: descriptive statistic of variables

Variable	Description	Mean	Std. dev	min	max
Innovated	Dummy = 1 if firms develop some innovation	0,23	0,42	0	1
	Firm´s characteristic				
Age	Years of the firm since its creation.	20,4	15,19	2	176
Qualified employment	Percentage of employees with tertiary education, masters and doctorate.	0,41	0,36	0	1
Micro	Dummy = 1 when firm has employees <11	0,28	0,45	0	1
Small	Dummy = 1 when firm has 11 <= employees <26	0,20	0,4	0	1
Medium	Dummy = 1 when firm has 26 <= employees < 201	0,36	0,48	0	1
Large	Dummy = 1 when firm has employees =>201	0,14	0,35	0	1
Spending in R&D activities	Per capita spending on R+D	2.178,05	8.399,01	0	177.777,8
	Firm´s environment				
Export	Dummy = 1 if firm export.	0,12	0,33	0	1
Group	Dummy = 1 if firm belongs to group.	0,12	0,43	0	1

	Economic activity				
Agricultural	Dummy = 1 if the firm belongs to the agricultural sector.	0,13	0,33	0	1
Manufacturing	Dummy = 1 if the firm belongs to the manufacturing sector.	0,31	0,46	0	1
Service	Dummy = 1 if firm belong service sector.	0,56	0,56	0	1

Export is a dichotomic variable indicating whether the firm exported in the survey period. Participation in foreign markets implies stronger competition, and the need for firms to adapt to international consumers (Aboal and Garda, 2016; Agwu et al., 2019; Carboni and Russu, 2018; Crespi and Zuniga, 2012; Egbetokun et al., 2015; García-Piqueres et al., 2020; Karlsson and Tavassoli, 2016; Mardones and Zapata, 2019). **Group** is a dummy variable that indicates whether the firm belongs to a group of companies. If so, then the firm will have access to information from different markets and, therefore, may adopt innovations in a transversal way as a group strategy and not necessarily of the firm in particular (Agwu et al., 2019; Egbetokun et al., 2015; García-Piqueres et al., 2020; Geldes et al., 2017).

The third group of variables is **economic activity**. For this purpose, we included three dummies, **agricultural, manufacturing**, and **services**, to indicate and differentiate the activities in which firms participate (Álvarez et al., 2015; Gallego et al., 2012; Geldes et al., 2017; Karlsson and Tavassoli, 2016).

3.3. Estimation Strategy

Probit or logit models are typically used to analyze the determinants of firms' propensity to innovate. When examining the four types of innovation as separate decisions, researchers have used multivariate probit models to test for correlations between innovation types (Agwu et al., 2019; Carboni and Russu, 2018; García-Piqueres et al., 2020). Researchers have also used a two-step approach to approximate firm decisions. The first stage explains the decision on whether to innovate and the second stage explains the type of innovations developed. This can be done from an econometric perspective using a combination of probit and multinomial logit models (Du et al., 2007). Other authors have also used count data and Poisson models to consider the integer nature of innovations (Martinez-Ros and Labeaga, 2010).

A relevant element in innovation studies is the potential existence of endogeneity. Endogeneity occurs when there is a structural association between innovation and innovation indicators (Cozzarin, 2016; Evangelista and Vezzani, 2010) or when unobserved factors lead firms to invest more in innovation activities (Cassiman and Veugelers, 2002; Crespi and Zuniga, 2012). Since we only observe firms that carry out R&D activities, there could be a reverse causality issue between innovation and R&D expenditures. Endogeneity results in biased and inconsistent parameters.

Instrumental variables are a classical solution for the endogeneity problem. An instrument must meet two conditions; it must be correlated with the endogenous variable $cov(x_i, Z) \neq 0$ and uncorrelated with the regression errors $cov(x_i, Z) = 0$. Studies on longitudinal data use lags of the explanatory variables since they are good instruments with predictive power (Anzola-Román et al., 2018; Evangelista and Vezzani, 2012). When used as an explanatory variable, firms' R&D expenditure is estimated by an auxiliary equation using a set of instruments that do not relate R&D expenditure with the propensity to innovate. Firms' predicted spending is then used as an explanatory variable in the innovation decision (Álvarez et al., 2011; Benavente, 2006; Crespi and Zuniga, 2012; Dachs et al., 2017; Hashi and Stojčić, 2013; Robin and Schubert, 2013; Stanovcic et al., 2015).

When analyzing the effect of organizational innovation on technological innovation, instrumental variables have been used for organizational innovation (Cozzarin, 2016; Hervas-Oliver et al., 2017). For R&D expenditure, Crespi and Zuniga (2012) and Álvarez et al. (2015) used explanatory variables such as the intensity of expenditure, patent protection, cooperation in R&D, public financing, and information activities. Aboal and Garda (2016) used public financing as an instrumental variable only. (Zemplinerová and Hromádková, 2012) used the obstacles to innovation as explanatory variables of the decision to invest in R&D, the intensity of expenditure, and the firm's sources of information.

2.4.4 Model specification

The firms face $i = 1, \ldots, 16$ possible decision strategies from the combinations of not innovating and developing the four innovations. To analyze how the dependent variables affect the decision strategy, we used the approach of Karlsson and Tavassoli (2016). Using a multinomial logit estimation, we estimated the parameters associated with the probability of choosing each possible strategy. The baseline decision for comparison is the strategy of not innovating. All parameters of this option are set to zero, and the estimated parameters are interpreted in comparison to the baseline alternative (Wooldridge, 2002). The probability that firm j $(j = 1, \ldots, N, N = 5500\, firms)$ chooses alternative i $(i = 1, \ldots, J, J = 16)$ is given by:

$$P_{ji} = Prob(y_{ji} = \frac{\exp(X_j^{'}\beta_i)}{1+\sum_{k=1}^{j}\exp(X_j^{'}\beta_k)} \qquad (1)$$

where j indicates that the firm decided to pursue strategy i i. X_j is the set of explanatory variables that describe firm characteristics (Table 2), and β_k is a set of parameters to be estimated. Note that there is a $J - 1$ (15) set of parameters, one for each alternative and$\beta_0 = 0$ for the baseline alternative. This equation allows us to obtain a set of probabilities for the J = 16 options that are available to firms when making innovation decisions.

To address the endogeneity problem, we used two instrumental variables. The first one was motivated by Crespi and Zuniga (2012), who suggested using lagged values of the variables from the first period of analysis for which we have information. In this paper, we used the lag of the skilled employees and export variables. We ran an auxiliary regression for R&D expenditure using the instruments. For this regression, we used patents, cooperation activities, market, institutional and other sources of information as instruments. We used the predicted R&D expenditure in the estimation of Equation (1). The first step equation is of the form:

$$RD_{it} = X_i^{'}\beta + Z_i^{'}\delta + \mu_i \qquad (2)$$

where RD_{it} is the per capita expenditure in R&D, X_i is the same set of explanatory variables used in Equation (1), and Z_i is a vector of instrumental variables that affect the firm´s RD_{it} but not the propensity to innovate (Aboal and Garda, 2016; Álvarez et al., 2011; Álvarez et al., 2015; Crespi and Zuniga, 2012). Results for Equation (2) are shown in the appendix[1].

2.5 Results

Table 1.3 presents the econometric results. We split the table into three groups: single strategies, semicomplex strategies that combine two innovations, and complex strategies that combine three or four innovations. Table 3 shows the

[1] A discussion of the instrumental variable used is presented in the appendix to chapter 3.

results after correcting for endogeneity; the uncorrected results are available in the appendix.

The most conspicuous result is that R&D is positive and statistically significant in all 15 strategies. The generation of knowledge through the company's R&D activities is relevant to increase the probability of all innovation strategies. Age and having fewer employees are never statistically significant, which contradicts with the expected results that younger firms should innovate in product and marketing (Plehn-Dujowich, 2009). At the same time, older companies should innovate in process or organizational innovation to find efficiency in internal processes. The results are highly heterogeneous for the remaining explanatory variables.

Regarding simple strategies, most explanatory variables are statistically significant only for organizational innovation. The quality of employees and medium and large size have a positive impact on the probability of organizational innovations, while exports have a negative impact (which is only significant at the 10% level). Additionally, regarding economic activities, given the character of the final good, manufacturing companies show a higher probability of innovating in products or marketing for the visibility of their goods. At the same time, service companies are more likely to choose a marketing innovation strategy, which is the most appropriate way to present their proposal to consumers. Both manufacturing and service industries are less likely to choose process innovation. Large firms are more likely to innovate in processes than small and medium firms. Firms that belong to a group are less likely to innovate in processes. Regarding the firm's environmental variables, the results indicated that exporting firms are more likely to innovation in products as they must compete and adapt to foreign markets, abut are less likely to choose organizational innovation.

When examining the role of firm characteristics in firms' decisions for a semicomplex innovation strategy, having skilled employees increased the probability of choosing a joint product and organizational innovation strategy. Medium and large firms were more likely to choose a strategy that combines process and organizational innovation. However, large firms were also more likely to choose product and organizational innovations or processes and marketing. Meanwhile, exporting firms were less likely to choose a joint process and organizational strategy. In terms of economic activity, manufacturing and service firms were more likely to choose a nontechnological innovation strategy (organizational plus marketing) compared to agricultural firms.

Finally, for complex innovation strategies, the size of the firm is relevant. Medium-sized firms were more likely to choose a strategy that combined product, process, and organizational innovation. Large firms had a greater likelihood of selecting four out of five complex strategies (this effect was not statistically significant for the innovation strategy that combined process, organizational, and marketing). Firms that belonged to a group were more likely to choose a complex strategy that includes all four types of innovation because such complex strategies are more feasible to develop among different firms within the group. Exporting firms were less likely to choose a strategy that includes product, process, and organizational innovations. Compared to firms in the agricultural sector, manufacturing and service firms are more likely to choose a complex innovation strategy of the four types of innovation. No significant effects were found in the case of the other four complex strategies.

In general, we can summarize the results as follows. First, access to resources is relevant for implementing an innovation strategy, which is shown by the effect that firm characteristics have on the probability of choosing an innovation strategy. Firm size and skilled employees positively affect innovation strategies, whether simple, moderately complex, or complex. Second, firm size is also relevant. The results show that large firms are more likely to choose different and especially innovation strategies than other firms. This decision is related to the possibility of using economies of scope in the innovation decision. Medium-sized firms are more likely to choose strategies that incorporate organizational and process innovation to search for efficiency in their growth process, which supports our hypothesis.

Third, firms' learning and knowledge acquisition capacity is a relevant resource for the choice of innovation strategy As skilled employees increase the probability of organizational innovation. For the remaining strategies, learning capacity is determined by R&D effort. For all strategies, R&D expenditure increases the probability of carrying out any innovation strategy, whether it be simple, moderately complex, or complex. Fourth, we did not find significant results regarding firm age to support our hypothesis.

Fifth, firms´ environmental variables have some effects on the choice of innovation strategy. Exporting firms tend to decide against efficiency-seeking strategies (process or organizational). Firms belonging to a group are more likely to choose a complex strategy but possibly as a conglomerate decision rather than as an individual decision.

Finally, correcting for endogeneity (see Appendix A) has a major impact on the loss of statistical significance of the parameters of firm size and belonging to a group of firms. In particular, the small firm variable was statistically significant in process innovation strategy (single strategy) and product, process, and organizational strategy (complex strategy). The medium-sized firm variable was statistically significant in process (single strategy), process with marketing, and process with product (semicomplex strategies), and three complex strategies, including the combination of the four types of innovations. Belonging to a group was statistically significant in organizational and marketing (single strategies) and in process plus organizational (semicomplex) and one complex strategy (process, organizational, and marketing). These changes show that correcting for endogeneity is relevant to evaluating the effect of different explanatory variables on innovation strategies.

Table 1.3: Result for diferent strategies

Table 3	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
n	88	189	132	113	34	106	20	109	40	80	110	32	35	109	183
Firm´s Characteristics															
Age (Ln)	-0,05	0,18	0,03	-0,19	0,36	-0,0006	0,45	0,068	0,27	0,065	-0,1	0,01	-0,17	0,048	-0,08
	(0,75)	(0,12)	(0,81)	(0,2)	(0,17)	(0,99)	(0,2)	(0,65)	(0,26)	(0,71)	(0,49)	(0,96)	(0,49)	(0,75)	(0,51
Qual.	-0,34	-0,14	0,67**	-0,4	0,92*	0,057	-1,07	-0,025	0,11	0,17	0,48	-0,5	-0,06	-0,087	0,05
Employ.	(0,33)	(0,53)	(0,014)	(0,15)	(0,09)	(0,85)	(0,16)	0,93)	(0,81)	(0,61)	(0,12)	(0,36)	(0,91)	(0,77)	(0,83)
Small	0,22	0,39	0,43	-0,29	-0,44	0,23	0,99	0,39	-0,89	0,45	0,51	0,84	-0,48	-0,38	0,16
	(0,53)	(0,11)	(0,15)	(0,31)	(0,53)	(0,49)	(0,22)	(0,37)	(0,28)	(0,2)	(0,18)	(0,21)	(0,57)	(0,32)	(0,56)
Medium	0,26	0,32	0,66**	-0,23	0,31	0,23	0,029	1,21***	0,58	0,05	0,78**	0,67	0,39	0,18	0,042
	(0,41)	(0,14)	(0,013)	(0,35)	(0,52)	(0,42)	(0,97)	(0,00)	(0,24)	(0,88)	(0,016)	(0,27)	(0,49)	(0,52)	(0,86)
Large	-0,25	0,68**	0,91**	-0,32	1.05*	0,56	0,53	1,6***	0,99*	0,21	1,42***	1,51**	1,56**	0,56	0,52*
	(0,56)	(0,012)	(0,006)	(0,36)	(0,07)	(0,07)	(0,56)	(0,00)	(0,08)	(0,61)	(0,00)	(0,02)	(0,01)	(0,1)	(0,07)
Ln (R+D)	0,88***	0,75*	0,61***	0,65***	0,86***	0,82***	0,91***	0,77***	0,9***	0,8***	0,96***	0,9***	0,93***	0,98***	1,03***
	(0,00)	(0,06)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Firm´s environment															
Export	0,45*	-0,05	-0,5*	0,33	-0,7	-0,19	0,62	-0,52*	-0,76	0,38	-0,74*	-0,28	0,19	-0,2	-0,25
	(0,09)	(0,79)	(0,087)	(0,23)	(0,18)	(0,47)	(0,25)	(0,07)	(0,11)	(0,2)	(0,01)	(0,95)	(0,56)	(0,46)	(0,25)
Group	0,045	-0,35*	0,11	0,3	-0,49	0,16	-0,18	0,25	-0,17	0,08	-0,29	-0,25	0,26	0,1	0,31*
	(0,86)	(0,06)	(0,56)	(0,18)	(0,24)	(0,49)	(0,74)	(0,24)	(0,64)	(0,76)	(0,21)	(0,54)	(0,48)	(0,63)	(0,08)
Economic activity															
Manuf.	0,72**	-0,41*	0,16	1,27**	-0,14	0,14	0,61	-0,32	1,1	1,06*	0,12	15,01	14,4	0,6	1,17***
	(0,07)	(0,06)	(0,62)	(0,01)	(0,8)	(0,65)	(0,44)	(0,29)	(0,14)	(0,08)	(0,71)	(0,98)	(0,98)	(0,15)	(0,00)
Service	0,43	-0,39*	0,15	1,7***	-0,18	-0,15	0,65	-0,22	0,78	1,57**	-0,04	15,72	15,29	0,89	1,05***
	(0,28)	(0,07)	(0,64)	(0,00)	(0,76)	(0,63)	(0,42)	(0,47)	(0,31)	(0,01)	(0,9)	(0,98)	(0,98)	(0,03)	(0,00)

2.6 Discussion

Firms that decide to innovate seek to change or improve their competitive position. A measure of success of innovation can be be increased sales, entrance into a new market, strengthening of position in the industry, and adapting to changes in the environment (González-Blanco et al., 2019; Karlsson and Tavassoli, 2016). Empirical evidence shows that innovative firms perform better in some of these indicators than those that do not innovate (Abdu and Jibir, 2018; Tavassoli and Karlsson, 2016). In this paper, we discuss how firms choose an innovation strategy (single, semicomplex, or complex) among four types of innovation options and a total of 16 possible combinations. The four innovations include both technological and nontechnological innovations: product, process, organizational, and marketing innovations. Our analysis complements the discussion regarding the multiple innovation decisions (not binary) among heterogeneous firms. This heterogeneity reflects varying resources and capabilities among firms which lead them to choose different innovation strategies for profit maximization (Agwu et al., 2019; Anzola-Román et al., 2018; Carboni and Russu, 2018; Fazlıoğlu et al., 2019).

2.6.1 Firm Antecedents on Innovation Strategy

Firm characteristics have diverse effects on innovation decisions. In our results, firms' effort to engage in R&D activities increases the probability of choosing any of the 15 possible strategies. Karlsson and Tavassoli (2016) used dichotomous variables to measure the development of internal and external R&D activities, showing that spending on R&D activities is only relevant in 12 strategies. Our results are also in line with the findings of Carboni and Russu (2018) and (García-Piqueres et al., 2020). Their results showed a positive and statistically significant effect of R&D spending on all types of innovation. Similar results were found by Aboal and Garda (2016) where the intensity of R&D expenditure positively affects the probability of the inclusion of technological and nontechnological innovations.

Another way to approximate firm capabilities is by firm size. Following Schumpeter (1942), we differentiated firms into four strata according to the number of employees. Our results indicated that larger firms are more likely to innovate, especially using complex strategies. This result is similar to the findings by Carboni and Russu (2018), Karlsson and Tavassoli (2016), Du et al. (2007), and Evangelista and Vezzani (2010). However, these papers do not differentiate by firm size.

In contrast to the results of García-Piqueres et al. (2020), firm size does have a positive and statistically significant effect on the probability of choosing organizational innovation. Indeed, medium-sized firms are more likely to choose organizational and process innovation, as shown by Anzola-Román et al. (2018) and Agwu et al. (2019). These strategies focused on knowledge management and searching for internal efficiency (Bartoloni and Baussola, 2018; Fazlıoğlu et al., 2019; Lee et al., 2019), as proposed by Černe et al. (2016), Cucculelli and Peruzzi (2020), Schubert (2010) and Plehn-Dujowich (2009), and this finding is relevant for medium-sized firms that are in the process of growth and must adapt their internal processes. We did not find significant evidence to support the hypothesis proposed by Álvarez et al. (2015), Arrow (1962), and Plehn-Dujowich (2009) that small firms tend to focus on product innovation (Mardones and Zapata, 2019) as they face more competition and must seek a market niche through differentiation.

Skilled employees are a relevant resource for developing innovations, as they allow firms to more quickly acquire knowledge and generate learning (Capozza and Divella, 2018; Milan et al., 2020). In our results, qualified employees only increase the probability of choosing two innovation strategies: product and organizational innovation. These results are consistent with the fact that organizational innovations involve knowledge management and, therefore, require a higher level of training for developing specific tasks or greater technical knowledge (Damanpour and Aravind, 2011; Gallego et al., 2012; Sapprasert and Clausen, 2012). This result is different from previous studies showing the relevance of firms' human capital for innovation decisions. For example, Karlsson and Tavassoli (2016) showed that human capital is a determinant of the choice of semicomplex and complex strategies, and Du et al. (2007) indicated that qualified employees decrease the probability of process innovation but increase the likelihood of product innovation (when analyzing only technological innovations). Furthermore, Tavassoli and Karlsson (2015) showed that human capital positively affects the propensity to innovate.

Regarding firms' environment, some authors have suggested that firms that compete in domestic markets and are open to international trade should focus on product innovation (Bhattacharya and Bloch, 2004; García-Piqueres et al., 2020). However, our results suggest that competition in foreign markets decreases the probability of choosing strategies that include process or organizational innovations. Our results are similar to those of Crespi and Zuniga (2012) on Chilean exporting firms and Aboal and Garda (2016) on Uruguayan manufacturing firms who found that these types of firms are less likely to develop technological innovations (including process innovation) and/or nontechnological innovations. Meanwhile, Agwu et al. (2019) showed how African exporting firms choose among the four types of innovations. Therefore, the literature has mixed results. Others suggested that exporting firms should innovate both in product and marketing (García-Piqueres et al., 2020) or process innovation (Carboni and Russu, 2018).

As Karlsson and Tavassoli (2016) showed, belonging to a group of firms shows few significant results. We observed that firms belonging to a group are less likely to choose a process innovation but are more likely to choose a complex strategy that includes all four types of innovation. Given that firms belonging to groups tend to be larger, this behavior can be explained by Schumpeter's proposal that larger firms have greater access to financing and capabilities to replicate and complement innovation strategies across multiple companies within the group. García-Piqueres et al. (2020) showed that firms belonging to a group of companies are more likely to innovate in products than in marketing, but Agwu et al. (2019) found that they are more likely to engage in organizational innovation and are less likely to innovate in products.

Finally, manufacturing firms, which are generally characterized as capital intensive firms that produce goods) generally opt for innovation in products and marketing (Evangelista and Vezzani, 2010; Geldes et al., 2017; Mothe and Nguyen-Thi, 2012, 2013) which was confirmed in our results analyzing decision among simple strategies. Nevertheless, other authors showed that manufacturing firms are more likely to choose a complex strategy. Karlsson and Tavassoli (2016) found that manufacturing firms are generally more likely to select complex strategies, but our results showed that manufacturing firms are more likely to choose only the complex strategy that combines all four types of innovation. Firms in the service sector are more likely to choose a nontechnological innovation strategy plus process innovation (Szczygielski et al., 2017) which allows them to be more efficient in internal processes and improve responsiveness to customers.

2.6.2 Endogeneity Issues

The results presented were obtained after correcting for endogeneity. However, doing so results in the loss of statistical significance on the effect of skilled employees in the semicomplex, product-organizational, and complex, product-process-organizational strategies. Belonging to a group of companies also loses significance in the choice of an organizational innovation strategy. Furthermore, we lose significance of small firm size in the process and product-process-organizational strategies, which implies no significant effects for this type of firm. Nevertheless, whether a firm is an exporter becomes significant in the choice of a product strategy after correcting for endogeneity.

2.6.3 Limitations and Future Research

This study is subject to some limitations that should be considered when interpreting and applying its findings. First, similar to how Eurostat's CIS has been utilized in studies on innovation strategy, the Chilean Innovation Survey has limitations such as single firm responses, potential inaccuracy in survey answers, and availability of control variables. Using more granular data in future research on innovation strategy could enrich the results found in this paper. Second, our sample only includes Chilean firms. However, our results are mostly aligned with that of previous studies based on country samples from Europe.

Confirmations on data from other countries (after considering endogeneity issues) as presented in this study are recommended. Finally, further examinations of firm characteristics on innovation strategy from a dynamic lens could reveal the changes in the type of innovation combinations that firms choose to implement over time.

2.7 Conclusions

Extensive literature has analyzed the determinants of innovation decisions at the firm level. This discussion has been extended to explore the determinants of types of innovation: product, process, organizational, and marketing. However, given the heterogeneity of firms, especially in level access to resources available for the development of innovations, it is relevant to analyze the possibility of joint development of innovations.

Considering the possibility of complementarity in the use of resources, and the resulting joint development of innovations, we analyzed the firms' choice of innovation strategy from the 16 possible combinations that exist with the four types of innovation. For this discussion, we used a set of variables that characterize the firm's resources and environment to analyze their impact on the choice of innovation strategy, including agricultural, manufacturing, and service firms.

Using a multinomial logit model, we analyzed the characteristics of the firms that determine the probability of choosing an innovation strategy compared to the baseline scenario of no innnovation. The main result is that regardless of the type of strategy (simple, semicomplex, or complex), the intensity of firms' R&D expenditure is relevant for deciding on any of the possible innovation strategies.

Considering the heterogeneity of firms' resources, firms that have more skilled employees will opt for innovation strategies that include organizational innovation. Medium-sized firms tend to choose strategies that include organizational innovation along with process innovation. Large firms tend to choose complex innovation strategies given their ability to generate economies of scale in the utilization of resources. When a firm faces larger external markets, it must focus on a product strategy given the need to adapt to the requirements of external customers and does not seek internal efficiency with a process innovation strategy.

However, these results are corrected for the existence of endogeneity in innovation studies. After correcting for endogeneity, we observed changes in the significance of skilled employees, exporting firms, and firms belonging to a group of companies.

For managers, these results imply that firm heterogeneity should not be a constraint for developing innovations. Rather, it should be an opportunity to focus decision-making efforts on innovations that can obtain a higher return given the resources used. Despite the relevance of R&D activities, firms should not necessarily focus on only one type of innovation (often either product or process innovation), but consider complementarity decisions, which can occur given firm resources or stage of growth. By reducing the possibility of imitation, combining innovation strategies also contributes to the developing a competitive advantage.

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Appendix 1 Results of percapita R&D expenditure equation

Variable	Parameter
Age	-0,068 (0,15)
Qualifield employment	0,56 *** (0,00)
Small	0,16 * (0,071)
medium	0,44 *** (0,00)
Large	0,37 *** (0,001)
Export	0,59 *** (0,00)
Group	0,12 (0,10)
Manufacturing	0,014 (0,89)
Service	-0,076 (0,44)
Patente	1,69 *** (0,00)
Cooperation	3,89 *** (0,00)
market information sources	0,39 *** (0,00)
Institutional information sources	-0,31 ** (0,012)
Other sources	0,39 *** (0,00)

Appendix 2: Results estimates for simple strategies

	1	2	3	4
Strategy	pr	pc	o	m
Innovated (firms)	88	189	132	113
Age (Ln)	-0,07	0,17	-0,0004	-0,20
	(0,69)	(0,17)	(0,99)	(0,18)
Qualified Employment	-0,98	-0,22	0,91***	-0,33
	(0,79)	(0,40)	(0,002)	(0,28)
Small	0,36	0.52 *	0,51	-0,22
	(0,35)	(0,05)	(0,109)	(0,47)
Medium	0,53	0,54 **	0,81***	-0,10
	(0,11)	(0,03)	(0,004)	(0,70)
Large	0,14	0,93 ***	1,02 ***	-0,24
	(0,75)	(0,002)	(0,003)	(0,50)
Export	0,41	-0,31	-0,74 ***	0,33
	(0,16)	(0,2)	(0,015)	(0,23)
Group	0,32	-0,10	0,36 *	0,55 **
	(0,25)	(0,62)	(0,097)	(0,023)
Spending I+D (Ln)	0,78	0,78***	0,66***	0,69***
	(0,00)	(0,00)	(0,00)	(0,00)
Manufacturing	0,98**	-0,15*	0,27	1,47***
	(0,02)	(0,56)	(0,43)	(0,008)
Service	0,70	-0,08	0,22	1,95 ***
	(0,11)	(0,74)	(0,51)	(0,00)

Appendix 3: Results estimates for semi complex strategies

	5	6	7	8	9	10
Strategy	pr + o	pr + m	pc + o	pc + m	pp + pc	o + m
Innovated (firms)	34	20	109	40	106	80
Age (Ln)	0,31	0,42	-0,01	0,23	-0,011	0,03
	(0,24)	(0,23)	(0,94)	(0,35)	(0,94)	(0,85)
Qualified	1,18**	-1,25	-0,09	0,082	0,052	0,44
Employment	(0,038)	(0,12)	(0,78)	(0,87)	(0,88)	(0,21)
Small	-0,33	1,17	0,58	-0,72	0,47	0,55
	(0,65)	(0,16)	(0,21)	(0,39)	(0,20)	(0,13)
Medium	0,57	0,38	1,51***	0,91*	0,61*	0,25
	(0,26)	(0,64)	(0,00)	(0,08)	(0,06)	(0,45)
Large	1,41 **	1,15	1,97***	1,53***	1,08***	0,45
	(0,018)	(0,22)	(0,00)	(0,01)	(0,008)	(0,29)
Export	-0,57	0,40	-0,82 ***	-0,72	-0,47	0,43
	(0,26)	(0,47)	(0,009)	(0,12)	(0,11)	(0,15)
Group	-0,23	0,01	0,51**	0,07	0,39	0,37
	(0,59)	(0,98)	(0,032)	(0,84)	(0,12)	(0,18)
Spending I+D	0,75***	0,92***	0,80***	0,85***	0,9***	0,67***
(Ln)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Manufacturing	0,04	1,03	-0,07	1,41*	0,44	1,23 *
	(0,93)	(0,20)	(0,82)	(0,07)	(0,22)	(0,05)
Service	0,028	1,17	0,09	1,21	0,17	1,75 ***
	(0,96)	(0,18)	(0,78)	(0,13)	(0,64)	(0,005)

Appendix 4: Results estimates for complex strategies

	11	12	13	14	15
Strategy	pr + o + m	pc + o + m	pr + pc + o	pr + pc + m	pr + pc m + o
Innovated (firms)	35	109	110	32	183
Age (Ln)	-0,21	-0,02	-0,11	-0,023	-0,086
	(0,41)	(0,87)	(0,49)	(0,93)	(0,53)
Qualified	-0,10	0,13	0,76**	-0,55	0,41
Employment	(0,98)	(0,69)	(0,02)	(0,34)	(0,15)
Small	-0,25	-0,12	0,67 *	1,05	0,40
	(0,77)	(0,75)	(0,09)	(0,13)	(0,20)
Medium	0,84	0,52*	1,15***	1,09 *	0,52 *
	(0,16)	(0,09)	(0,001)	(0,09)	(0,06)
Large	2,27***	1,08***	2,06***	2,17***	1,41***
	(0,001)	(0,004)	(0,00)	(0,003)	(0,00)
Export	0,25	-0,30	-0,83***	0,034	-0,23
	(0,56)	(0,30)	(0,009)	(0,94)	(0,33)
Group	0,50	0,43 *	0,02	-0,016	0,59***
	(0,20)	(0,081)	(0,9)	(0,96)	(0,004)
Spending I+D	0,88***	0,82***	0,83***	0,89***	0,93***
(Ln)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Manufacturing	14,53	0,89 **	0,32	15,05	1,47***
	(0,98)	(0,04)	(0,39)	(0,98)	(0,00)
Service	15,51	1,16**	0,16	15,9	1,37 **
	(0,97)	(0,01)	(0,67)	(0,98)	(0,001)

CHAPTER 2: INNOVATION DECISION: DO TECHNOLOGICAL AND NON-TECHNOLOGICAL INNOVATIONS COMPLEMENTS EACH OTHER

3.1 Abstract

When a firm decides to innovate, it may innovate in product, process, organization, marketing, or some combination of these. The literature defines two possible theoretical models for conceptualizing these innovations. First, the *innovation strategy* approach assumes that these types of innovations are independent. Second, the *complementary approach* assumes that non-technological innovations (organizational and marketing) are inputs for technological innovations (products and processes). Using data from innovation surveys in Chile, Ecuador, Colombia, and Spain, this study tests which framework fits the data better. We analyze both decision models using multinomial logit and multivariate probit models. Further, we compare these approaches using Akaike and Bayesian information criteria. The results consistently show that a multivariate probit model is more adequate for explaining a firm's innovation decisions. The joint development of non-technological innovations and organizational and process innovations show the highest correlations. Finally, regardless of the model, spending on innovation activities positively affects all types of innovations and strategies, along with skilled employees and firm size.

Keywords: complementary innovation, innovation strategy, information criteria.

Jel classification: C35, L21, O32

3.2 Introduction

The literature on a firm's innovation identifies four primary innovation alternatives: product, process, organizational, and marketing (Mothe and Thi, 2010). The first and last two are technological and non-technological innovations, respectively. Firms can develop technological and non-technological innovations either together or separately (D'Attoma and Ieva, 2020; Gupta et al., 2016; Naidoo, 2010; Quaye and Mensah, 2018). Given these four options and their possible combinations, it is evident that analyzing only the propensity to innovate or looking at only one type of innovation may generate biases, thus potentially misleading public policies (Anzola-Román et al., 2018; Birkinshaw et al., 2008; García-Piqueres et al., 2020; Hecker and Ganter, 2013a; Mothe and Nguyen-Thi, 2012; Schmidt and Rammer, 2006, 2007).

A vast majority of the literature has addressed dichotomous innovation decisions (yes/no), with a significant prevalence of technological innovations (Damanpour and Aravind, 2011; Khosravi et al., 2019; Pippel, 2014). This study provides valuable insights into how firms' characteristics and environment affect their propensity to innovate. Moreover, the Oslo manual´s definition of *organizational and marketing innovations* opens up a range of new combinations of innovations for firms that needs to be reconsidered in modern analyses (Anzola-Román et al., 2018; Černe et al., 2016; Khosravi et al., 2019; Mothe and Nguyen-Thi, 2012; Schubert, 2010). This new classification allows us to better understand the innovation decision process and the relationship between different types of innovations. The joint development of innovations allows the optimization of resources (Carboni and Russu, 2018) and takes advantage of synergies. Furthermore, it may be motivated by the imitation of other companies, managerial characteristics, and the favorable presence of financial and economic resources for innovation (García-Piqueres et al., 2020).

We found at least two competing theoretical approaches for understanding the relationship between technological and non-technological innovations. First, under the "*joint innovation development*," also called ***strategies*** (Karlsson and Tavassoli, 2016), the four types of innovations can be developed independently, and firms can choose any combination among them (Agwu et al., 2019; Carboni and Russu, 2018; Du et al., 2007; García-Piqueres et al., 2020; Hecker and Ganter, 2013b; Schubert, 2010). Second, the "*complementarity theory*" claims that non-technological innovations are inputs for developing technological innovations (Mothe et al., 2015; Mothe and Thi, 2010). Therefore, when firms develop non-technological innovations, they have a higher propensity to create technological innovations than those that do not develop organizational or marketing innovations (Anzola-Román et al., 2018; Camisón and Villar-López, 2014; Cozzarin, 2017; Geldes et al., 2017; González-Blanco et al., 2019).

This study contributes to the literature in several ways. First, we evaluate which of these two interpretations is supported by data from different countries. While both the theories describe the possibility of the joint development of innovations, there is little empirical evidence comparing these approaches and evaluating their goodness-of-fit. This gap is critical because it informs us which one provides a better description of firm decisions (Anzola-Román et al., 2018; Černe et al., 2016; Khosravi et al., 2019; Mothe and Nguyen-Thi, 2012; Serrano-Bedia et al., 2018). Second, unlike previous studies that used only the R2 criterion to compare models, we base our analysis on information criteria (Akaike and Bayesian) that are more suitable for comparing non-nested and nonlinear models. Third, we contribute to the scarce literature that includes four types of innovations in the analysis. Finally, we use instrumental variables to control for the potential existence of endogeneity when R&D expenditure is used as an explanatory variable.

We describe these theoretical approaches using two econometric models. The ***innovation strategy*** is estimated using a multinomial logit model suggested by Karlsson and Tavassoli (2016) that considers all 16 possible combinations of innovation strategies (including the option of not innovating). Under the **complementary theory**, we use a multivariate probit model suggested by Carboni and Russu (2018) and García-Piqueres et al. (2020). This model has a system of four equations, one for each innovation type. We analyze the correlation between the four equations to determine whether there is a joint development of innovations and estimate the four equations with and without incorporating non-technological innovations as explanatory variables (inputs) in the technological equations.

We use the Akaike, Akaike corrected, and Bayesian information criteria (AIC, AICc, BIC) to compare the models (de Deus et al., 2020; Emiliano et al., 2014; Önder, 2016; Rinke and Sibbertsen, 2016; Weiß and Martin, 2020). To generalize our results as much as possible, we estimate the model for four countries (Chile, Ecuador, España, and Colombia).

Our results reveal that the (partially) *complementary theory* fits the data better. Furthermore, the multivariate probit models outperform the multinomial logit model in 3 out of the four countries. While this implies that the utilization of non-technological and technological innovations occurs together, our models also suggest that organizational and marketing innovations are not inputs for product and process innovations. When including non-technological innovations as inputs, the effect is unexpectedly negative on product and process innovations and sometimes not statistically significant. However, this model does not outperform the multivariate probit model without non-technological innovation as an input. This new result contradicts the findings of Gallego et al. (2012), Hervas-Oliver et al. (2017), Mothe and Thi (2010), and Mothe and Nguyen-Thi (2012) who demonstrate a positive effect of non-technological innovations on product or process innovations. Nevertheless, our application differs from the previous literature in that we use a system of equations that includes all four types of innovations while other studies have analyzed product and process innovations using independent regressions that do not consider the possible correlations among innovations.

3.3 Brief Literature Review

A vast majority of literature discusses the determinants of firm innovation by comparing innovating firms with non-innovating firms using a dichotomous decision approach (yes/no). This approach provides helpful information regarding firms´ characteristics that affect the probability and effect of innovations on firm performance (Aboal and Garda, 2016; Álvarez et al., 2015; Benavente, 2005; Benavente, 2006; Crespi and Zuniga, 2012; Dachs et al., 2017; Hashi and Stojčić, 2013). However, this approach does not shed light on the type of innovation chosen by firms, either technological or non-technological (Carboni and Russu, 2018; Cozzarin, 2017; García-Piqueres et al., 2020; Hecker and Ganter, 2013a, 2016; Karlsson and Tavassoli, 2016; Mothe and Thi, 2010; Tavassoli and Karlsson, 2016).

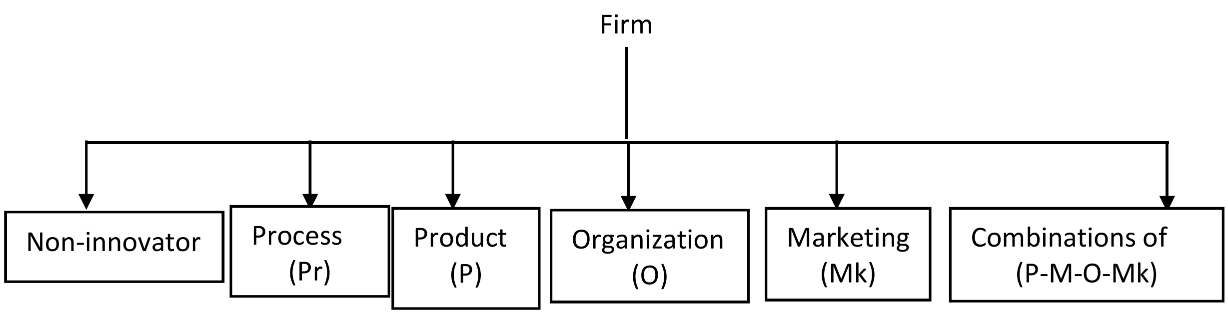
Many of the innovation studies focus on the role of R&D expenditure as the main input, however, many innovation activities are not based on R&D. There are specific factors that affect the firm's innovative behavior such as the internal capabilities to generate knowledge supported by the organizational structure, the firm's absorptive capacity given by the training, quality, skills and competencies of the employees and characterized in the firm's internal routines; the firm's history that implies the accumulation of knowledge over time along with the firm's life cycle (Karlsson and Tavassoli, 2016; Tavassoli and Karlsson, 2016). According to the definition of Barney and Griffin (1992) these specific factors are called human, social, physical, organizational resources. These resources affect the firm's innovation decisions in terms of making the best use of them. Firms have a unique combination of tangible and intangible resources, which allows them to direct a competitive advantage through innovation and even more so when they are supported by intangible assets due to the difficulty of copying them by the competition (Andersen, 2012; Bakar and Ahmad, 2010; Laosirihongthong et al., 2014).

The Oslo manual’s (Manual, 2005) identification of organizational and marketing innovations (non-technological) as an extension of product and process innovations (technological) opens the floor to discussion regarding how these innovations are incorporated in the decision process. Besides analyzing the determinants of each type of innovation, a new issue arises: What is the relationship between technological and non-technological innovations? For Karlsson and Tavassoli (2016), firms´ decision involved deciding over 16 possible innovation strategy portfolios. These strategies result from combinations of the four available innovations and the option of not innovating.

Figure 2.1 shows this approach. In this case, the possibility of joint innovation development leads firms to choose among a set of 16 possible innovation strategies. These strategies can be simple, intermediate, or complex depending on the number of innovations implemented (Schubert, 2010). In this approach, innovation strategies are perfect substitutes to each other as firms decide on only one of them. Using multinomial logit models, Du et al. (2007) and Karlsson and

Tavassoli (2016) analyze the joint decision of innovations. They analyze different innovations. While Du et al. (2007) analyzed only technological innovations and discussed a better fit for the innovation decision, Karlsson and Tavassoli (2016) examined They differ in the type of innovations they analyze the joint decision of the 16 innovation strategies given the four types of innovations.

Figure 2.1: Innovation strategy: Technological and Non-technological innovations as outputs.



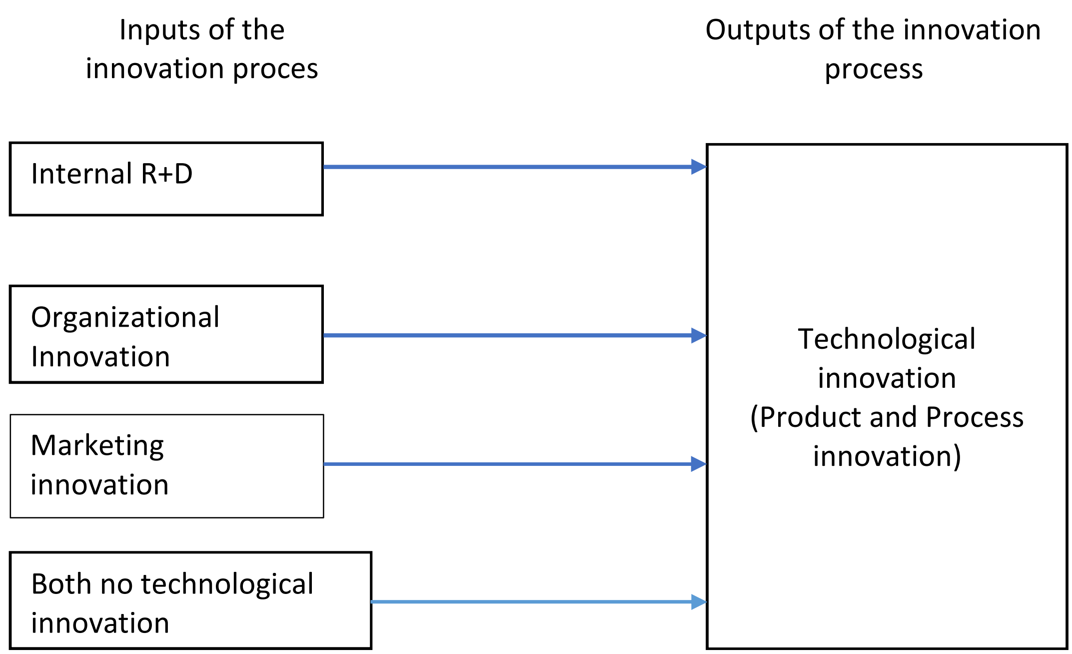
Source: Adapted from Du et al. (2017)

Alternatively, according to Carboni and Russu (2018), the decision process is a joint decision among the four possibilities (*complementary approach*). As firms must use resources for innovation activities and access to them is limited and heterogeneous, the organizational structure is a relevant element that supports change and innovation development. Organizational innovation provides firms with flexibility and skills for change, defined as complementary and prerequisite activities that facilitate product and process innovation development (Armbruster et al., 2008; Černe et al., 2016). Therefore, firms should benefit from the joint implementation of technological and organizational innovations (Sapprasert and

Clausen, 2012). Further, organizational innovations are specific to a firm's internal processes. Therefore, they turn into unrepeatable and inimitable work practices that can lead to technological changes and innovations (Anzola-Román et al., 2018; Camisón and Villar-López, 2014; Sapprasert and Clausen, 2012). Additionally, they strengthen the competitive advantage of a firm and make it more difficult to imitate (Armbruster et al., 2008; Černe et al., 2016; Khosravi et al., 2019).

Marketing innovations, which have scarcely been analyzed in the literature (D'Attoma and Ieva, 2020; Serrano-Bedia et al., 2018), affect the introduction of new products in the market, for example, by adjusting the product offering. Therefore, they have a potential relationship with technological innovations (D'Attoma and Ieva, 2020; Schubert, 2010) and affect firm performance (Aas and Pedersen, 2011; Grimpe et al., 2017; Naidoo, 2010; Nieves and Diaz-Meneses, 2016). In addition, it is a tool used when firms have a low level of R&D expenditure but must compete to show their attributes in competitive distribution channels (Mothe and Nguyen-Thi, 2012).

Figure 2.2: Complementarity Theory: Non-technological innovations as an input of technological decisions.



Source: Adapted from Anzola-Román et al. (2018).

Figure 2.2 presents a simple scheme to understand the complementarity theory. This Figure shows nontechnological innovations as the inputs for technological innovations. This implies that organizational and marketing innovations can be determinants of technological innovation (Anzola-Román et al., 2018; Cozzarin, 2017; Ganter and Hecker, 2013; Hecker and Ganter, 2016; Hervas-Oliver et al., 2017; Mothe and Nguyen-Thi, 2012; Mothe et al., 2015; Woschke and Haase, 2016). Theoretically, this idea is supported by the fact that organizational innovation involves the development of learning capabilities that take time and allow the introduction of product or process innovations. Empirical studies have used probit models to model innovation decisions within this framework. The nontechnological innovations are included as explanatory variables in the propensity to innovate a product or process. Some results highlight that organizational innovation affects technological innovations, even in small-and medium-sized companies (Gallego et al., 2012), while the results are inconclusive for the development of innovations and marketing.

Carboni and Russu (2018), García-Piqueres et al. (2020), and Agwu et al. (2019) use a multivariate probit model but includes only three types of innovations. In this study, we extend their analysis by including four types of innovations. This approach allows us to identify the determinants of each type of innovation separately (product, process, organizational, and marketing). Furthermore, it allows us to identify the probability of joint implementation between technological and non-technological innovations through an analysis of their correlations. For instance, some authors have shown a relevant correlation between process and organizational innovation (Carboni and Russu, 2018; García-Piqueres et al., 2020) or product and process innovation (Agwu et al., 2019). However, none of these studies discuss the possibility of firms using organizational and marketing innovations as inputs for product or process innovations.

These two competing theories have been analyzed separately in the literature. This study compares these in terms of information criteria. A few previous studies include Hervas-Oliver et al. (2017), who analyze whether management innovation affects technological innovations or vice-versa. Their results revealed that management innovation positively and significantly affects technological innovations. Geldes and Felzensztein (2013) analyze marketing innovation decisions (packing, design, and distribution) in agricultural firms using logit estimations and introduce product, process, and organizational innovation as determinants of marketing innovation, among other variables. Their results showed that process innovation has a positive effect on distribution. Concomitantly, there is a negative and significant relationship between some types of organizational innovation and marketing innovation in design and distribution. They analyze innovations in aggregate form, and the results show a negative and significant relationship between product innovation and marketing innovation. These authors used only the coefficient of determination R2 as a goodness-of-fit criterion for comparison.

3.4 Material and Methods

3.4.1 Data[2]

[2] Its is possible to acces the research data by contacting the corresponding author

We use innovation surveys from four countries: Chile, Colombia, Ecuador, and Spain. For Chile, we use the 2015–2016 survey. In Colombia, development and technological innovation surveys were conducted for manufacturing companies during 2017–2018 and service companies during 2018–2019. For Ecuador, we use the survey of science, technology, and innovation activities for 2012–2014, while in the case of Spain, we use the company innovation survey from 2016. These surveys follow the guidelines of the Oslo Manual. They provide information on the characteristics of companies and allow us to analyze the development of products, processes, and organizational and marketing innovations.

The surveys contain information on R&D activities, among others, related to innovation. The Chilean version includes more than 5,000 firms. Approximately 23% of them indicate development of innovation. The sample size from Ecuador has more than 6,000 firms, and 57% indicated development of some innovation. In Colombia, the survey has approximately 7,000 manufacturing companies, with 21% developing some type of innovation, and 9,000 service firms, with 24% innovating. Finally, the sample from Spain comprises more than 7,000 firms, with 61% of them carrying out innovations.

Table 2.1: Innovation Strategies for countries

Country	Chile	España	Ecuador	Colombia	
				Manufacture	Service
Innovator	1380 (23,48%)	4668 (60,75%)	3557 (56,66%)	1572 (20,78%)	2222 (11,28%)
Product	88	565	283	274	406
Process	189	356	462	360	265
Product + process	106	390	368	190	98
Only tech	*383 (28%)*	*1311 (28%)*	*1113 (31%)*	*824 (52%)*	*769 (35%)*
Organizational	132	437	474	76	330
Marketing	113	165	302	106	230
Organizational + Marketing	80	218	237	31	96
Only no tech	*325 (24%)*	*820 (17%)*	*1013 (28%)*	*213 (14%)*	*656 (30%)*
Product + organizational	34	161	113	48	144
Product + marketing	20	146	94	62	67
Process + organizational	109	269	235	66	127
Process + marketing	40	70	110	62	70
Product + organizational + marketing	35	214	82	20	56
Process + organizational + marketing	109	219	131	35	74
Product + process + organizational	110	460	243	83	120
Product + process + marketing	32	157	165	79	36

Product + process + marketing + organizational	183	841	258	80	103
Total other combination	*672(49%)*	*2537 (54%)*	*1431 (40%)*	*535 (34%)*	*797 (36%)*

Table 2.1 shows the distribution of companies by type of innovation, differentiating when the firm develops only technological innovation or only non-technological innovation. Except in the case of Colombian manufacturers, less than 35% of the firms developed only technological innovations, and less than 30% of the firms developed only non-technological innovations. Moreover, more than 40% of the firms developed some innovation mixing technological and non-technological innovations. Only 38% of the innovative companies developed only one type of innovation, while the rest carried out a combination of two or more innovations. Spain has the highest percentage of firms developing several innovations, while Colombia’s manufacturing sector has the lowest rate.

3.4.2 Statistical Model and Explanatory variables

Tavassoli and Karlsson (2016) propose a production function of the Coob Douglas type described by $Q_{it} = AK_{it}^{\beta 1} L_{it}^{\beta 2}$ where the parameter A is a knowledge input. Several studies have discussed that the operationalization of A corresponds to the firm's innovation output, using mainly product or process innovation for it and is referred to as the knowledge production function (Griffith et al., 2006; Polder et al., 2010). On the other hand, Plehn-Dujowich (2009) present a production function of the form $P = AR^{\alpha}$ where P refers to the innovation output (measured in patent) and R as the R&D expenditure.

For our work the parameters A and P refer to the firms' innovation output. For this purpose our knowledge production function has as an outcome the development of some innovation strategy or the complementarity in the development of innovations. And for each of these options we define an econometric estimation strategy.

We use two econometric approaches to analyze firms' innovation decisions, and define three estimation strategies. First, a multinomial logit allows us to incorporate the 16 possible innovation combinations (presented in Table 1) suggested by Karlsson and Tavassoli (2016). Second, we use a multivariate probit model in which a system of four equations (an equation for each type of innovation) is estimated. This model allows us to characterize the relationship between technological and non-technological innovation by examining the correlation coefficients among the four types of innovation.

The multinomial logit (model 1) has the form:

$$P_{ji} = Prob\left(y_{ji} = 1\right) = \frac{\exp(X_j'\beta_i)}{1+\sum_{k=1}^{J}\exp(X_j'\beta_k)} \quad (1)$$

Pij is the probability that firm j chooses strategy i with i = 1, ..., 16. We define three subgroups of strategies. Simple strategies involve the development of only one type of innovation: semi-complex strategies, which involve the development of two innovations simultaneously, and complex strategies that involve the development of three or four innovations at the same time. We use instrumental variables to control for endogeneity when R&D expenditure was used as an explanatory variable. We use a two-step model. First, we estimate an equation for R&D spending given by:

$$RD_{it} = X_I^{`}\beta + Z_I^{`}\delta + \mu_I \qquad (1`)$$

where RD_{it} is the per capita expenditure on R&D, X_i is the same set of explanatory variables used in equation (1), and Z_i is a vector of instrumental variables that affect a firm´s RD, but not the propensity to innovate (Aboal and Garda, 2016; Álvarez et al., 2011; Álvarez et al., 2015; Crespi and Zuniga, 2012). Additionally, we use patents, cooperative activities, market information sources, institutional information sources, and other information sources as instruments. The results for Equation (1´) are presented in Appendix 1. In the second step, we use the predicted value of R&D to estimate Equation 1.

For the complementarity model (Carboni and Russu (2018)), we use a multivariate probit model with the following equations:

$$y_{j,pr} = \beta_i^{'} X_j + \delta_0 * y_{jorg} + \delta_m * y_{jmk} + \varepsilon_{pr} \quad (2.1)$$

$$y_{j,pc} = \beta_i^{'} X_j + \delta_0 * y_{jorg} + \delta_m * y_{jmk} + \varepsilon_{pc} \quad (2.2)$$

$$y_{j,org} = \beta_i^{'} X_j + \mu_{org} \quad (2.3)$$

$$y_{j,mk} = \beta_i^{'} X_j + \mu_{mk} \quad (2.4)$$

The dependent variable, $y_{j,i}$ is a dichotomous variable that takes a value of one if the i-th innovation is chosen. Subscript j refers to the firm. We use the subscript *pr* for product innovation, *pc* for process innovation, *org* for organizational innovation, and *mk* for marketing innovation (i = process, product, organization, and marketing). This set of equations considers the possible complementarity between non-technological and technological innovations by including in equations 2.1 and 2.2 the organizational and marketing innovations as explanatory variables of product and process innovations. Additionally, we estimate the model as a system of seemingly unrelated regression (SUR), where only the errors are correlated.

In the multivariate probit, the correlation between the different types of innovation is captured by the correlation of the error terms. This correlation also captures the existence of omitted variables. For instance, if innovations are jointly developed, the correlation coefficient should be positive and statistically significant after controlling for other explanatory variables (Carboni and Russu, 2018; Serrano-Bedia et al., 2018). A statistically significant correlation coefficient suggests that the model accurately describes the decision-making process and controls for endogeneity.

3.4.3 Model Selection Criteria

Traditionally, the coefficient of determination R^2 is used to measure the goodness of fit and compare models (de Deus et al., 2020). However, this indicator does not provide adequate information, because it has a positive relationship with the inclusion of more explanatory variables. Additionally, it only works for linear models. Researchers rely on information criteria to compare non-nested models that differ in number of parameters (de Deus et al., 2020; Önder, 2016; Rinke and Sibbertsen, 2016; Weiß and Martin, 2020). These criteria lean towards models that explain the phenomenon in the simplest possible way, following the principle of parsimony (de Deus et al., 2020). These criteria balance sensitivity (sufficient parameters to accurately explain the relationship between data) with specificity (not suggesting existing patterns or relationships) (Dziak et al., 2020). They balance the goodness of fit and model complexity using a loss function defined as (Rinke and Sibbertsen, 2016):

$$L = G(\hat{\sigma}^2) + P(n, p)$$

$G(\hat{\sigma}^2)$ is associated with the goodness-of-fit depending on the estimation procedure, whereas the second term, $P(n, p)$ is a penalty function that depends on the sample size (n) and the number of parameters (p). The objective is to reduce the risk of overfitting the model; therefore, they provide a standardized method of balancing sensitivity and specificity (Dziak et al., 2020). From the set of estimated models, these criteria choose the one that delivers the minimum value of the function (Weiß and Martin, 2020).

The literature suggests two main decision criteria (Rinke and Sibbertsen, 2016; Weiß and Martin, 2020), the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Emiliano et al., 2014): They are defined as follows:

$$AIC = -2 * LogL(\hat{\theta}) + 2(p)$$

$$BIC = -2 * LogL(\hat{\theta}) + p * log(n)$$

Emiliano et al. (2014) highlighted that AIC can exhibit poor performance if there are many parameters related to the sample size because it has a fixed penalty factor (Weiß and Martin, 2020). BIC has a stronger penalty factor, increasing the number of parameters with respect to AIC to avoid overfitting in small samples (Rinke and Sibbertsen, 2016).

3.4.4 Explanatory variables

We included the same set of explanatory variables defined among groups of firm characteristics and traditionally used in studies on innovation decision determinants in the three decision models. Table 2.2 shows the descriptive statistics of the variables. The first group of variables aims to characterize the firm: *the age of the firm,* calculated as the difference between the survey´s year and the firms´ creation. This variable represents the learning process over time, which allows for the accumulation of knowledge and experience during the life cycle. *Skilled employees* are the percentage of a firm's workers with a higher education. This is used as a proxy for a firm's absorptive capacity to represent the possibility of acquiring knowledge. *Firm size*, which is the number of employees characterized by intervals of workers differentiating between micro, small, medium, and large firms, represents the firm's access to resources that allow the development of specific innovations or the possibility of accessing economies of scale or scope. The development of R&D activities is incorporated as the variable *R&D expenditure,* which is the per capita expenditure on all R&D activities, and represents the firm's efforts to generate internal and external knowledge to develop innovations.

The second group of variables measures the environmental effects on a firm's decisions. Export is a dichotomous variable that takes a value of one for a firm that participates in external markets. More competitive markets are expected to affect the development of innovations to adapt to the characteristics sought by consumers. *The group* characterizes whether the firm belongs to a group of companies (dichotomous variable). Belonging to a larger group allows the company to access more information from different market participants. Therefore, it enables them to develop innovations in a cross-cutting manner among companies to take advantage of the economies of scope.

Finally, the third group of variables controls for economic activities. We use dichotomous variables to indicate whether the firms belong to the agricultural, manufacturing, or service sectors.

Notably, in the case of Colombian firms, the year of the start of operation of the firms is not given; therefore, we do not have the age of the firms. For Spanish firms, we do not indicate economic activity.

Table 2.2: Descriptive statistics

Variable	Description	Chile	España	Ecuador	Col. Manuf.	Col. Serv.
Innovated	Dummy=1 if firms developed some innovations	0,23 (0,42)	0,6 (0,48)	0,56 (0,49)	0,21 (0,41)	0,11 (0,31)
Firm´s Characteristics						
Age	Years of the firm since its creation	20,4 (15,19)	33,2 (20,8)	18,09 (14,18)		
Qualified employment	Percentage of employees with tertiary education, mastres and doctorate	0,41 (0,36)	0,29 (0,29)	0,30 (0,27)	0,32 (0,22)	0,49 (0,32)
Micro	Dummy = 1 when firm has employees <11	0,28 (0,45)	0,14 (0,34)	0,09 (0,29)	0,12 (0,33)	0,05 (0,22)
Small	Dummy = 1 when firm has	0,20 (0,4)	0,16 (0,37)	0,38 (0,48)	0,29 (0,45)	0,15 (0,35)

	11 <= employees <26					
Medium	Dummy = 1 when firm has 26 <= employees < 201	0,36 (0,48)	0,41 (0,49)	0,39 (0,48)	0,44 (0,49)	0,57 (0,49)
Large	Dummy = 1 when firm has employees =>201	0,14 (0,35)	0,27 (0,44)	0,12 (0,32)	0,12 (0,33	0,22 (0,41)
Spending in R&D activities	Per capita spending on R+D	533,66 (3723,43)	7786,22 (114326,7)	3090,2 (132625,5)	1181 (7.484)	1.030 (6.963)
Firm´s Environment						
Export	Dummy = 1 if firm export.	0,12 (0,33)	0,47 (0,49)	0,12 (0,33)	0,28 (0,45)	0,07 (0,25)
Group	Dummy = 1 if firm belongs to group.	0,12 (0,00)	0,46 (0,49)	0,17 (0,38)	0,033 (0,17)	0,05 (0,22)
Economic activity						
Agricultural	Dummy = 1 if the firm belongs to the agricultural sector.	0,13 (0,33)		0,03 (0,19)		
Manufacturing	Dummy = 1 if the firm belongs to the manufacturing sector.	0,31 (0,46)		0,25 (0,45)		
Service	Dummy = 1 if the firm belongs to the service sector.	0,56 (0,56)		0,70 (0,45)		

3.5 Results and discussion

The complete set of estimations, including all explanatory variables, is presented in the Appendix. Appendices 1 to 5 present the results of the multinomial logit model (equation 1), while appendices 6 to 10 present the results of the multivariate probit model (equations 2.1 to 2.4). We first discuss the general results that are common to all regressions. Then, we compare the theoretical frameworks using information criteria. The main results are presented in Table 3, which shows the information criteria for each model.

3.5.1 Results on the explanatory variables in both models

First, R&D expenditure has a positive and statistically significant effect on the selection of any innovation alternative in all countries and empirical models. These results are consistent with those reported by Karlsson and Tavassoli (2016), Du et al. (2007), Carboni and Russu (2018), Agwu et al. (2019), García-Piqueres et al. (2020), and Hecker and Ganter (2013b). They find that spending on R&D has a positive effect on firms' innovation. It is also relevant to note that we used firms' total expenditure on R&D activities in this study. By contrast, other studies differentiate between types of R&D activities or between internal and external expenditures.

We observe a statistically significant effect of *age* in multinomial logit regressions for Ecuador and Spain, affecting the decision of an innovation strategy in a product or process in conjunction with organizational innovations. In the multivariate probit model, *age* affects organizational (Ecuador), process, and marketing innovation (Spain). Older firms develop this type of innovation (organizational or process) and search for internal and external process efficiencies (Camisón and Villar-López, 2014). Berulava and Gogokhia (2016), who analyze combinations of technological and non-technological innovations under the CDM model, find no significant effect of *age*. However, Agwu et al. (2019) show that *age* has a positive impact on product, process, and organizational innovation.

As a proxy for a firm's ability to absorb and acquire knowledge for the development of innovations, *skilled employees* have a positive impact on the decision of Chilean and Spanish firms in strategies that include organizational innovation, whereas in Ecuador, it is relevant for the decision of any type of strategy. In Colombian manufacturing, this variable is relevant to semi-complex strategies that include marketing innovation. Furthermore, for Colombian firms' services, *skilled employees* positively affect strategies that include technological and organizational innovation. This finding is similar to that of Ramírez et al. (2019). This result indicates the need for skilled employees to develop innovations that involve acquiring knowledge for changes in the company's internal processes or the relationship with external actors in the organization, such as suppliers or customers.

Access to resources is relevant for developing innovation and is correlated with firm size. Schumpeter (1934) indicates that larger firms are in a better position to innovate because they have access to more financing or the possibility of taking advantage of economies of scope in developing innovation. Our results show that medium and large firms are more prone to choosing semi-complex and complex strategies (two or more strategies). This result is also found by Agwu et al. (2019), where large firms are more likely to innovate among the four types of innovation. In contrast, García-Piqueres et al. (2020) and Carboni and Russu (2018) find no statistically significant effect of firm size on organizational innovation. However, these two studies do not differentiate firms according to size. In the case of service firms in Colombia, we find no statistically significant effect of firm size on the decision to innovate in marketing.

We found that medium-sized firms decide on process and organizational innovations (individually or jointly), contrary to Gallego et al. (2012), who showed that organizational innovation does not affect the development of technological innovations in medium-sized firms.

Small Colombian firms (manufacturing and service companies) seem to have chosen product innovation. As Arrow (1962) indicates, product innovation is a decision that must be made to differentiate itself in competing markets. Chilean firms, which also decide to innovate products, also develop process and organizational innovations. For the results of small Spanish firms, we see that they decide for all four types of innovation. By contrast, small Ecuadorian firms have a higher probability of choosing organizational and marketing innovations.

Exporting firms face more competitive markets than the domestic market; therefore, product and marketing innovation is more relevant in differentiating themselves and achieving market niches (García-Piqueres et al., 2020). We observe this in the results of the multivariate probit model for Spanish, Colombian manufacturing, and Chilean firms. However, Agwu et al. (2019) show that exporting firms tend to choose one of four types of innovation. Carboni and Russu (2018) showed a positive effect on product and process innovation. The results from the countries analyzed are mixed, with a clear effect of exporting firms on product innovation. In Chile, exporting firms also choose marketing innovation, but not organizational innovation. These results are similar to those presented by García-Piqueres et al. (2020), who reported a positive effect of exporting firms on the probability of choosing a product and marketing innovation.

Regarding the economic activity of the firms, we see that in terms of strategy decisions, manufacturing firms in Chile and Ecuador decide to develop a simple product and marketing strategy or a complex strategy for the four innovations. When we examine the individual decision to innovate for Ecuadorian firms, the results show a positive effect for manufacturing and service firms on the decision to innovate in marketing. By contrast, Chilean firms decide on organizational and marketing innovations. As Mothe and Nguyen-Thi (2012) show, marketing innovation positively affects the probability of innovation for manufacturing and service firms, whereas organizational innovation only has a positive effect on service firms.

3.5.2 Results associated with the multivariate probit model

Gallego et al. (2012), Hervas-Oliver et al. (2017), Mothe and Nguyen-Thi (2012), and Mothe and Thi (2010) study the influence of organizational or marketing innovation on technological innovation. Extending these works, we included all non-technological innovations as determinants of each technological innovation and used a system of equations with the four types of innovation. When we analyze non-technological innovations as inputs to product and process innovations, our results show that organizational and marketing innovations negatively affect product and process innovation. We found that marketing innovation has a negative effect on process innovation in Chile, Ecuador, Spain, and Colombia. In the case of Colombian service and manufacturing firms, we find a negative effect of organizational innovation on both technological innovations. These results contrast with those presented by Mothe and Thi (2010) and Mothe and Nguyen-Thi (2012). They find a positive effect of organizational marketing on product innovation. Furthermore, Hervas-Oliver et al. (2017) and Gallego et al. (2012) show a positive effect of organizational innovation on technological innovation. These studies analyze product and process innovations using independent regressions, whereas we consider the possible correlation between innovations using four simultaneous equations in the model. Geldes et al. (2017) found similar results: there is a negative relationship between product innovation and marketing innovation.

When non-technological innovations are included as inputs in Chilean firms, the parameter associated with R&D expenditure increases. Gallego et al. (2012) show that when including organizational innovation as a determinant of technological innovation, the effect of R&D intensity has a positive effect only in small and large firms and not in medium-sized firms. Hecker and Ganter (2013a) indicate that the intensity of R&D spending is relevant to organizational innovation because of the complementarity between the types of innovation developed by firms. They also introduce R&D processes that increase process efficiency.

3.5.3 Comparison of models using information criteria[3]

Table 2.3 lists the AIC and BIC. In the first column, *Mlogit* corresponds to the estimation of equation 1, *MVprobit* corresponds to equation 2, assuming $\delta_o = \delta_m = 0$ (nontechnological innovations do not directly affect technological innovations), and *Mvprobit inputs* to equation 2 but $\delta_o \neq 0 \; and \; \delta_m \neq 0$. Table 3 indicates that the appropriate way to describe companies' joint innovation process is through a ***multivariate probit model***. In other words, the complementarity

[3] We did the AICc calculations but there are no changes in the results. In addition, the literature indicates that it is relevant when the ratio (n/p) is less than 40, a situation that only occurs in Chile

model appears better for most countries. The results show that the multinomial logit (innovation strategy theory) better describes firms' innovation decisions only in Ecuador.

Table 2.3: Results information criteria

	Chile		**Ecuador**		**Colombia Manufacturing firms**		**Colombia Service firms**		**España**	
	AIC	*BIC*	*AIC*	*BIC*	*AIC*	*BIC*	*AIC*	*BIC*	*AIC*	*BIC*
Mlogit	12.286	13.383	**24.650**	**25.762**	11.475	12.306	17.114	17.970	30.345	31.281
MV probit	10.401	**10.733**	26.103	26.440	11.450	**11.712**	16.331	**16.602**	29.240	**29.531**
MV probit-inputs	**10.401**	10.760	26.108	26.440	**11.442**	11.732	**16.304**	16.603	**29.235**	29.555

In the four estimations where the multivariate probit (complementarity model) provides the best fit, we see a difference between the AIC and BIC. BIC always shows the lowest value for the MV probit, without considering non-technological innovations as inputs in technological innovations. A different penalty for over-parameterization could explain this result, which allows us to say that the BIC is a better criterion than the AIC. Nevertheless, choosing information criteria has substantial implications for the model's specifications. The AIC suggests that non-technological innovations are inputs for technological innovations. In contrast, the BIC suggests that they are not but that they are still correlated.

Table 2.4 shows the correlation coefficients obtained in the multivariate probit between the possible combinations of the four innovation types. The correlation coefficients are statistically significant and positive in both estimations (with and without considering nontechnological innovations as inputs). In other words, there is joint development of innovation in firms.

In black, we highlight the three highest correlations for each estimate. We observe that non-technological innovations have higher correlation coefficients. The highest correlations in the four estimations are as follows: organizational and marketing innovations and joint development of organizational and process innovations. The latter pair is oriented towards the search for internal efficiency in companies (González-Blanco et al., 2019; Hecker and Ganter, 2013a) and is associated with medium and large companies.

Table 2.4: Correlation between innovation pairs.

Correlation	Chile		Colombia Manufacture		Colombia Service		España	
	No inputs	inputs	No inputs	inputs	No inputs	Inputs	No inputs	Inputs
Process-product	**0,56**	**0,61**	0,22	0,31	0,16	0,39	0,33	0,38
Organizational-product	0,48	**0,62**	0,28	**0,48**	0,19	**0,61**	0,25	0,22
Marketing-prodcut	0,37	0,56	0,31	0,34	0,16	0,37	0,33	0,34
Organizational-process	**0,57**	0,53	**0,36**	**0,58**	**0,34**	**0,61**	**0,48**	**0,60**
Marketing-product	0,41	0,57	0,31	**0,47**	**0,30**	**0,57**	**0,35**	**0,84**
Marketing-organizational	**0,63**	**0,63**	**0,43**	0,42	**0,32**	0,32	**0,59**	**0,59**

Note: All correlations are statistically significant.

These results show that companies jointly develop innovations and complement each other in the pursued objectives. Nevertheless, this complementarity is captured mainly by the correlation of the error terms, and does not seem to be structural. In other words, adding non-technological innovations as inputs in technological innovations does not contribute to increasing the goodness of fit. We can conclude that the four innovations are not independent and are jointly developed. This feature is common to both the theoretical frameworks. The overparametrization of the multinomial logit models (innovation strategies framework) significantly penalizes the goodness of fit of this model.

3.6 Conclusion

We compare the two theoretical frameworks used in the literature to analyze the relationship between different innovations. On the one hand, the vision of *innovation strategy* is a defined set of all possible innovation combinations. On the other hand, the *complementarity framework* suggests that non-technological innovations are inputs to technological innovations. We use a multinomial logit for the first framework and a multivariate probit model for the complementary framework. Our empirical approach incorporated four types of innovation into the analysis: product, process, organizational, and marketing.

The information criteria suggest that the multivariate probit model describes firms' decisions better. These results show that companies jointly develop innovations and complement each other. Nevertheless, this complementarity is captured mainly by the correlation between the error terms. Adding nontechnological innovations as inputs to technological innovations does not increase the goodness of fit. This feature is common to both the theoretical frameworks. Nevertheless, the overparametrization of the multinomial logit models (innovation strategies framework) significantly penalized the goodness of fit of this model.

In particular, we see a high correlation in Chile, Ecuador, Colombia, and Spain in the joint development of organizational and marketing innovations, together with organizational and process innovation. This complementarity of organizational innovation provides empirical support for the joint development of technological and non-technological innovations. It also allows firms to develop improvements in internal processes by acquiring knowledge through the different activities involved in organizational innovation. Moreover, it is a source of competitive advantage that is difficult to imitate.

3.7 Reference

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Chile	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
n	88	189	132	113	34	106	20	109	40	80	110	32	35	109	183
Firm´s Characteristics															
Age (Ln)	-0,05	0,18	0,03	-0,19	0,36	-0,0006	0,45	0,068	0,27	0,065	-0,1	0,01	-0,17	0,048	-0,08
	(0,75)	(0,12)	(0,81)	(0,2)	(0,17)	(0,99)	(0,2)	(0,65)	(0,26)	(0,71)	(0,49)	(0,96)	(0,49)	(0,75)	(0,51
Qual.	-0,34	-0,14	0,67**	-0,4	0,92*	0,057	-1,07	-0,025	0,11	0,17	0,48	-0,5	-0,06	-0,087	0,05
Employ.	(0,33)	(0,53)	(0,014)	(0,15)	(0,09)	(0,85)	(0,16)	0,93)	(0,81)	(0,61)	(0,12)	(0,36)	(0,91)	(0,77)	(0,83)
Small	0,22	0,39	0,43	-0,29	-0,44	0,23	0,99	0,39	-0,89	0,45	0,51	0,84	-0,48	-0,38	0,16
	(0,53)	(0,11)	(0,15)	(0,31)	(0,53)	(0,49)	(0,22)	(0,37)	(0,28)	(0,2)	(0,18)	(0,21)	(0,57)	(0,32)	(0,56)
Medium	0,26	0,32	0,66**	-0,23	0,31	0,23	0,029	1,21***	0,58	0,05	0,78**	0,67	0,39	0,18	0,042
	(0,41)	(0,14)	(0,013)	(0,35)	(0,52)	(0,42)	(0,97)	(0,00)	(0,24)	(0,88)	(0,016)	(0,27)	(0,49)	(0,52)	(0,86)
Large	-0,25	0,68**	0,91**	-0,32	1.05*	0,56	0,53	1,6***	0,99*	0,21	1,42***	1,51**	1,56**	0,56	0,52*
	(0,56)	(0,012)	(0,006)	(0,36)	(0,07)	(0,07)	(0,56)	(0,00)	(0,08)	(0,61)	(0,00)	(0,02)	(0,01)	(0,1)	(0,07)
Ln (R+D)	0,88***	0,75*	0,61***	0,65***	0,86***	0,82***	0,91***	0,77***	0,9***	0,8***	0,96***	0,9***	0,93***	0,98***	1,03***
	(0,00)	(0,06)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Firm´s environment															
Export	0,45*	-0,05	-0,5*	0,33	-0,7	-0,19	0,62	-0,52*	-0,76	0,38	-0,74*	-0,28	0,19	-0,2	-0,25
	(0,09)	(0,79)	(0,087)	(0,23)	(0,18)	(0,47)	(0,25)	(0,07)	(0,11)	(0,2)	(0,01)	(0,95)	(0,56)	(0,46)	(0,25)
Group	0,045	-0,35*	0,11	0,3	-0,49	0,16	-0,18	0,25	-0,17	0,08	-0,29	-0,25	0,26	0,1	0,31*
	(0,86)	(0,06)	(0,56)	(0,18)	(0,24)	(0,49)	(0,74)	(0,24)	(0,64)	(0,76)	(0,21)	(0,54)	(0,48)	(0,63)	(0,08)
Economic activity															
Manuf.	0,72**	-0,41*	0,16	1,27**	-0,14	0,14	0,61	-0,32	1,1	1,06*	0,12	15,01	14,4	0,6	1,17***
	(0,07)	(0,06)	(0,62)	(0,01)	(0,8)	(0,65)	(0,44)	(0,29)	(0,14)	(0,08)	(0,71)	(0,98)	(0,98)	(0,15)	(0,00)
Service	0,43	-0,39*	0,15	1,7***	-0,18	-0,15	0,65	-0,22	0,78	1,57**	-0,04	15,72	15,29	0,89	1,05***
	(0,28)	(0,07)	(0,64)	(0,00)	(0,76)	(0,63)	(0,42)	(0,47)	(0,31)	(0,01)	(0,9)	(0,98)	(0,98)	(0,03)	(0,00)

Ecuador	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
N	283	462	474	302	113	368	94	234	110	237	243	165	82	131	258
Firm´s Characteristics															
Age (Ln)	-0,23***	-0,16**	-0,11	0,01	-0,27**	-0,03	-0,01	-0,32***	-0,2	-0,12	-0,25***	-0,26	-0,23	-0,27***	-0,11
	(0,00)	(0,02)	(0,07)	(0,88)	(0,03)	(0,62)	(0,46)	(0,00)	(0,12)	(0,16)	(0,00)	(0,01)	(0,10)	(0,02)	(0,21)
Qual. Employ.	3,6***	3,2***	0,79***	0,35	-4,3***	3,9***	-4,2***	2,5***	3,2***	1,09***	3,8***	-3,06***	3,8***	2,7***	3,8***
	(0,00)	(0,00)	(0,00)	(0,22)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Small	0.55***	-0,51***	0,78***	0,01	0,15	-0,03	1,35**	-0,41	-0,43	0,45	-0,31	-0,11	0,32	0,29	0,70
	(0,02)	(0,01)	(0,00)	(0,93)	(0,72)	(0,90)	(0,04)	(0,18)	(0,21)	(0,09)	(0,31)	(0,75)	(0,56)	(0,55)	(0,06)
Medium	-0,88***	-0,84***	1,1***	0,01	0,22	0,21	0,38	-0,26	-1,00***	0,79***	0,24	-0,36	0,44	0,34	0,96***
	(0,00)	(0,04)	(0,00)	(0,57)	(0,61)	(0,43)	(0,57)	(0,38)	(0,00)	(0,00)	(0,42)	(0,32)	(0,42)	(0,47)	(0,00)
Large	-1,8***	-2,0***	0,83***	-0,29	-1,2**	-0,14	-1,01	-1,2***	-1.94***	0,35	0,02	-0,28	-0,39	-0,99*	0,52
	(0,00)	(0,00)	(0,00)	(0,41)	(0,02)	(0,65)	(0,20)	(0,00)	(0,00)	(0,39)	(0,95)	(0,49)	(0,54)	(0,08)	(0,19)
Ln (R+D)	-8,9***	-9,1***	-1,17***	-0,42***	.8,9***	-8,04***	-9,2***	-8,9***	-8,4***	-1,25***	-7,7***	-7,5***	-8,4***	-8,38***	-7,1***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Firm´s environment															
Export	1,0***	0,97***	0,23	-0,31	0,77**	0,61***	0,97***	1,1***	0,76**	-0,54*	0,61*	0,75***	0,33	1,04***	0,56***
	(0,00)	(0,00)	(0,18)	(0,20)	(0,02)	(0,00)	(0,00)	(0,00)	(0,03)	(0,07)	(0,00)	(0,00)	(0,43)	(0,00)	(0,00)
Group	0,93***	-1,15***	0,03	0,21	0,72***	0,95***	0,82**	0,76***	0,58*	0,13	0,85***	0,97***	0,96***	0,94***	0,98***
	(0,00)	(0,00)	(0,82)	(0,23)	(0,01)	(0,00)	(0,01)	(0,00)	(0,07)	(0,51)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Economic activity															
Manuf.	-0,35	-0,13	-0,89***	1,2**	0,85	0,43	0,18	-0,78**	0,54	0,31	0,17	15,76	-0.69	14,91	2,7***
	(0,3)	(0,66)	(0,00)	(0,02)	(0,40)	(0,18)	(0,81)	(0,02)	(0,46)	(0,52)	(0,64)	(0,98)	(0,24)	(0,98)	(0,00)
Service	-2,8***	-2,15	-0,83***	1,03*	-1,11	-2,67***	-2,39***	-2,86***	-1,9*	0,42	-2,22	12,84	-2,6	12,75	-0,02
	(0,00)	(0,67)	(0,00)	(0,05)	(0,28)	(0,00)	(0,00)	(0,00)	(0,01)	(0,40)	(0,86)	(0,98)	(0,74)	(0,99)	(0,98)

España	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
N	565	356	437	165	161	390	146	269	70	218	460	157	214	219	841
								Firm´s Characteristics							
Age (Ln)	0,049	0,16	0,065	0,12	-0,11	0,26**	0,27	0,06	0,43*	-0,07	0,11	0,47***	0,16	0,41*	0,27
	(0,63)	(0,16)	(0,54)	(0,47)	(0,5)	(0,02)	(0,15)	(0,63)	(0,08)	(0,61)	(0,30)	(0,00)	(0,27)	(0,05)	(0,51)
Qual.	0,0007	-0,006**	0,008**	-0,005*	-0,0001	-0,004*	-0,004	-0,001	-0,01*	0,005**	-0,004*	-0,008**	0,005*	-0,004	-0,001
Employ.	(0,68)	(0,01)	(0,00)	(0,09)	(0,95)	(0,06)	(0,21)	(0,52)	(0,05)	(0,03)	(0,05)	(0,01)	(0,06)	(0,17)	(0,83)
Small	0,11	0,62**	0,22	-0,40	0,43	0,87***	0,004	0,96**	0,92	0,22	1,3***	1,35**	0,77**	0,98**	0,79
	(0,5)	(0,01)	(0,27)	(0,15)	(0,21)	(0,00)	(0,86)	(0,01)	(0,14)	(0,41)	(0,00)	(0,01)	(0,02)	(0,01)	(0,56)
Medium	0,26	0,74***	0,68***	-0,03	0,6*	1,02***	-0,26	1,88***	0,86	0,6**	2,02***	1,34**	1,18***	1,05***	1,44
	(0,12)	(0,00)	(0,00)	(0,9)	(0,07)	(0,00)	(0,35)	(0,00)	(0,16)	(0,01)	(0,00)	(0,01)	(0,00)	(0,00)	(0,86)
Large	-0,034	0,95***	-0,11***	0,28	0,87**	1,48***	0,01	2,3***	1,2**	1,4***	2,67***	1,66***	1,3***	1,54*	2,35*
	(0,86)	(0,00)	(0,00)	(0,31)	(0,01)	(0,00)	(0,95)	(0,00)	(0,06)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,07)
Ln (R+D)	0,52***	0,44***	0,17***	0,24***	0,63***	0,62***	0,48***	0,47***	0,49***	0,24***	0,72***	0,71***	0,58***	0,53***	0,73***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
								Firm´s environment							
Export	0,19***	-0,25**	-0,11	0,24	-0,26	0,26**	0,77***	-0,22	-0,03	0,05	-0,11	-0,14	0,42**	-0,24	0,08
	(0,00)	(0,04)	(0,36)	(0,19)	(0,14)	(0,04)	(0,00)	(0,12)	(0,90)	(0,73)	(0,37)	(0,45)	(0,01)	(0,12)	(0,25)
Group	0,01	0,18	0,1	-0,21	0,14	0,23**	-0,49	-0,08	0,22	-0,21	0,25	-0,26	-0,23	0,11	0,06
	(0,92)	(0,15)	(0,32)	(0,24)	(0,41)	(0,06)	(0,01)	(0,56)	(0,40)	(0,17)	(0,03)	(0,15)	(0,15)	(0,48)	(0,08)

Colombia Mnaufacturas	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
N	274	360	76	106	48	190	62	66	40	31	83	79	20	35	80
Firm´s Characteristics															
Qual. Employ.	0,20	-0,69**	0,29	0,51	-0,81	0,35	1,09*	-0,21	-0,35	1,9***	0,44	0,50	0,78	-0,61	1,67***
	(0,53)	(0,02)	(0,59)	(0,25)	(0,24)	(0,37)	(0,07)	(0,74)	(0,59)	(0,00)	(0,44)	(0,4)	(0,53)	(0,51)	(0,00)
Small	0,58	0,26	1,8	-0,015	1,04	0,46	0,12	-0,42	0,40	-0,5	-0,40	2,22	1,44	3,3*	0,31
	(0,17)	(0,39)	(0,14)	(0,97)	(0,32)	(0,37)	(0,88)	(0,71)	(0,54)	(0,51)	(0,64)	(0,13)	(0,61)	(0,07)	(0,76)
Medium	1,04**	0,90***	1,32*	0,15	1,07	0,72	0,84	1,66*	0,23	0,4	0,83	2,57*	2,07	5,44***	1,13
	(0,01)	(0,00)	(0,07)	(0,69)	(0,29)	(0,13)	(0,25)	(0,08)	(0,71)	(0,53)	(0,26)	(0,07)	(0,31)	(0,00)	(0,23)
Large	0,5	0,42	0,17	-0,22	0,76	0,60	0,59	1,59	-0,04	-0,19	0,35	2,69*	2,62	5,85***	1,30
	(0,24)	(0,19)	(0,82)	(0,62)	(0,46)	(0,23)	(0,44)	(0,10)	(0,54)	(0,80)	(0,65)	(0,06)	(0,32)	(0,00)	(0,18)
Ln (R+D)	1,09***	1,00***	0,95***	0,24***	1,18***	1,21***	1,17***	1,08***	1,17***	0,98***	1,3***	1,35***	1,47***	1,12***	1,2***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Firm´s environment															
Export	0,25	-0,17	0,20	0,10	-0,07	0,22	-0,03	-0,54*	-0,05	-0,66	0,15	-0,44	-0,92***	-0,82**	-0,09
	(0,10)	(0,20)	(0,43)	(0,63)	(0,83)	(0,23)	(0,89)	(0,06)	(0,85)	(0,12)	(0,55)	(0,10)	(0,00)	(0,03)	(0,73)
Group	0,06	-0,21	0,10	-0,82	0,32	-0,32	-0,43	0,81*	-0,31	-0,21	-0,09	0,07	0,04	-0,31	0,12
	(0,86)	(0,57)	(0,85)	(0,18)	(0,52)	(0,41)	(0,41)	(0,07)	(0,56)	(0,99)	(0,83)	(0,86)	(0,94)	(0,64)	(0,77)

Colombia servicios	Single strategies				Semi complex strategies						Complex strategies				
Strategy	P	Pr	O	M	P+O	P+Pr	P+M	Pr+O	Pr+M	O+M	P+Pr +O	P+Pr +M	P+O +M	Pr+O +M	P+Pr+ O+M
N	406	265	330	230	144	98	67	127	70	96	120	36	56	74	103
Firm´s Characteristics															
Qual. Employ.	1,76***	-0,43*	-0,04*	-0,90***	1,5***	1,10***	0,16	-0,21	-0,97**	-0,98***	1,4***	-0,19	1,7***	-0,7***	1,3***
	(0,00)	(0,04)	(0,04)	(0,00)	(0,00)	(0,00)	(0,71)	(0,49)	(0,01)	(0,00)	(0,00)	(0,74)	(0,00)	(0,00)	(0,00)
Small	0,6	0,84	1,05*	0,19	-0,46	1,25	3,9***	-0,74	-0,85	-1,13	-14,8	-0,16	1,45	-0,33	1,3
	(0,20)	(0,12)	(0,06)	(0,68)	(0,73)	(0,31)	(0,00)	(0,59)	(0,45)	(0,14)	(0,98)	(0,99)	(0,4)	(0,76)	(0,36)
Medium	0,76*	0.73	1,03**	0,42	1,8*	1,97*	3,5***	1,7*	0,5	-0,21	0,45	-1,38*	1,89	0,41	1,6
	(0,07)	(0,15)	(0,01)	(0,34)	(0,05)	(0,08)	(0,00)	(0,06)	(0,58)	(0,71)	(0,62)	(0,08)	(0,23)	(0,66)	(0,2)
Large	1,05**	0,92*	1,17**	-0,03	2,04**	1,93*	3,1***	1,9**	0,81**	-0,47	1,45	-0,63	2,25	0,62	2,3
	(0,01)	(0,07)	(0,03)	(0,94)	(0,03)	(0,09)	(0,00)	(0,04)	(0,37)	(0,44)	(0,11)	(0,42)	(0,15)	(0,51)	(0,07)
Ln (R+D)	0,93***	0,88***	0,84***	0,86***	1,1***	1,04***	1,16***	0,93***	0,91***	1,09***	1,14***	1,15***	1,1***	1,04***	1,2***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Firm´s environment															
Export	-0,4**	-0,39	0001	-0,78**	0,01	-0,44	0,34	-0,06	0,36	-0,35	0,16	0,27	-0,44	0,29	0,25
	(0,04)	(0,15)	(0,99)	(0,03)	(0,96)	(0,25)	(0,35)	(0,83)	(0,35)	(0,42)	(0,55)	(0,58)	(0,35)	(0,44)	(0,25)
Group	-0,66**	-0,98***	-0,73***	-0,9***	-0,88***	-0,8**	-1,16***	0,78***	-1,18***	-0,93***	-0,58**	-0,96**	-0,33	-0,67*	-0,59*
	(0,02)	(0,00)	(0,00)	(0,00)	(0,00)	(0,01)	(0,00)	(0,00)	(0,00)	(0,00)	(0,04)	(0,04)	(0,39)	(0,07)	(0,06)

In the multinomial logit results, age shows some positive and significant effects in Ecuador and Spain. In Ecuador, it affects the decision of firms in simple product or process strategies or complex strategies where these are included together with organizational or marketing. While in Spain age affects decisions about semi-complex strategies of technological innovation or complex strategies of technological innovation with marketing or organizational.

The results show that skilled employees have a significant effect on most strategies for companies in Ecuador and Colombia Service. In Ecuador, negative and significant effects are obtained for three strategies that include product innovation, while for the other strategies the effect of qualified employees is positive and significant. For firms in Colombia Services, there is a negative and significant effect for the marketing strategy and two strategies that include it, while for the rest of the strategies the effect is positive and significant. In the case of Spain, negative and significant effects are obtained for four strategies that include process innovation. For Colombian manufacturing firms, the positive and significant effect is for two semi-complex strategies that include marketing and the complex strategy of the 4 innovations as a whole, while in Chile the effect is significant only for 3 strategies that include organizational innovation.

Small firms in Ecuador have a higher probability of choosing a simple product or organizational strategy and a lower probability of processes. On the other hand, small Spanish firms are more likely to choose semi-complex strategies that include process or a complex strategy that combines three types of innovation. With respect to Chile and Colombia, no significant effects are obtained.

Medium-sized firms in Spain are more likely to choose a semi-complex or complex strategy. While in Colombia services firms choose a simple or semi-complex strategy. In the rest of the countries, the effects are more specific. In Chile the positive effect occurs in three strategies that include organizational innovation; in Ecuador, they choose non-technological innovation or the 4 innovations as a whole; finally, Colombian firms choose the simple product, process, or organizational strategies or a complex one that includes them.

Large firms are more likely to innovate than other firms in the four countries, however, innovation decisions are different. In the case of Spanish, the highest probability occurs in semi-complex and complex strategies. In Chile and Colombia manufacturing, these firms only present a higher probability of complex strategies. And for Ecuador and Colombia services the decision is for simple and semi-complex strategies.

Regarding the environment, exporting firms from Ecuador present a positive and significant effect on semi-complex and complex strategies. In contrast, firms from Colombia services have a negative effect on simple strategies. For Spanish firms, only two strategies have a positive effect (product and semi-complex product plus marketing); Colombia manufacturing presents a negative effect in strategies that include process or organizational innovation, and for Chile, the negative and significant effect occurs in strategies that include process innovation.

For the case in which the firms belong to a group in Colombia of services, the results show a negative and significant effect, positive and significant in Ecuadorian firms. But in Chile, the effect is positive and significant only in the complex strategy of the 4 types of innovation.

In Chile, manufacturing and service firms have a higher probability of developing non-technological innovation or a complex strategy of the 4 innovations as a whole. In Ecuador, service firms have a higher probability of not developing a simple or semi-complex innovation strategy, while manufacturing firms decide for a complex strategy of the 4 innovations at the same time.

Appendix 6: Chile

Innovation	Product		Process		Organizational		Marketing	
Variable	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3
Age (ln)	-0,03	-0,034	0,013	0,012	-0,025	-0,02	-0,034	-0,03
	(0,42)	(0,38)	(0,73)	(0,75)	(0,5)	(0,53)	(0,34)	(0,42)
Qual. Employment	0,12	0,13	0,013	-0,007	0,31 ***	0,31***	0,003	-0,0007
	(0,16)	(0,10)	(0,86)	(0,92)	(0,00)	(0,00)	(0,96)	(0,99)
Small	0,19 **	0,19**	0,2 **	0,18**	0,16 **	0,16 *	0,019	0,017
	(0,03)	(0,03)	(0,02)	(0,03)	(0,04)	(0,05)	(0,82)	(0,83)
medium	0,25 ***	0,26***	0,37 ***	0,34***	0,37 ***	0,37***	0,08	0,078
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,26)	(0,29)
Large	0,57 ***	0,60***	0,70 ***	0,67***	0,68 ***	0,68***	0,32 ***	0,30***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Export	0,006 *	0,009	-0,22 ***	-0,18**	-0,16 **	-0,16**	0,14 **	0,15**
	(0,09)	(0,90)	(0,00)	(0,01)	(0,01)	(0,01)	(0,04)	(0,03)
group	0,043	0,062	0,03 ***	0,037	0,12 **	0,12**	0,13 **	0,13**
	(0,5)	(0,31)	(0,00)	(0,54)	(0,03)	(0,03)	(0,02)	(0,02)
Ln (R+D)	0,27 ***	0,29***	0,30	0,31***	0,25 **	0,25***	0,24 ***	0,24***
	(0,00)	(0,00)	(0,60)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Org		-0,18		0,18				
		(0,36)		(0,42)				
Mark		-0,30*		-0,38				
		(0,08)		(0,04)				
Manufacturing	0,31 ***	0,36**	-0,0007	0,045	0,19 **	0,19 **	0,65 ***	0,62***
	(0,00)	(0,00)	(0,99)	(0,62)	(0,03)	(0,04)	(0,00)	(0,00)
Service	0,24 **	0,31	-0,026	0,037	0,24 ***	0,23 ***	0,81 ***	0,78***
	(0,01)	(0,00)	(0,76)	(0,69)	(0,00)	(0,01)	(0,00)	(0,00)
rho21	0,56 ***	0,61**		Rho32	0,57	0,53***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho31	0,48 ***	0,62***		Rho42	0,41	0,57***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho41	0,37 ***	0,56***		Rho43	0,63	0,63***		
	(0,00)	(0,00)			(0,00)	(0,00)		

Appnedix 7: Ecuador

Innovation	Product		Process		Organizational		Marketing	
Variable	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3
Age (ln)	0,009	0,011	0,009	0,009	-0,05 **	-0,05***	-0,009	-0,008
	(0,67)	(0,61)	(0,67)	(0,66)	(0,01)	(0,00)	(0,69)	(0,64)
Qual. Employment	0,78 ***	0,77***	0,44 ***	0,450***	0,33 ***	0,33***	0,27 **	0,27**
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,03)
Small	0,34 ***	0,34***	0,24 ***	0,24***	0,38 **	0,37***	0,24 ***	0,23***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Medium	0,52 ***	0,50***	0,44 **	0,43***	0,65 ***	0,65***	0,28 ***	0,28***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Large	0,91 ***	0,88***	0,80 ***	0,78***	0,70 ***	0,69***	0,31 ***	0,30***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Export	0,006	-0,02	0,02	0,009	0,02	0,02	-0,08	-0,08***
	(0,90)	(0,96)	(0,64)	(0,86)	(0,70)	(0,65)	(0,15)	(0,00)
Group	-0,017	-0,09	0,01	0,01	-0,04 **	-0,04***	0,035	0,04
	(0,72)	(0,83)	(0,81)	(0,67)	(0,34)	(0,00)	(0,48)	(0,73)
Gasto i+d (ln)	0,003	0,003	-0,03 **	-0,037**	-0,031 **	-0,03***	-0,02	-0,022***
	(0,80)	(0,82)	(0,01)	(0,01)	(0,04)	(0,00)	(0,2)	(0,00)
Org		0,16		-0,13				
		(0,52)		(0,66)				
Mark		-0,29		-0,47				
		(0,22)		(0,09)				
Manufacturas	0,68 ***	0,74***	0,69 ***	0,77***	-0,02	-0,02	0,77 ***	0,75***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,77)	(0,18)	(0,00)	(0,00)
Servicios	0,12	0,17	0,14	0,22**	-0,009	-0,008	0,58 ***	0,56***
	(0,27)	(0,10)	(0,11)	(0,03)	(0,91)	(0,94)	(0,00)	(0,00)
rho21	0,57 ***	0,61***		Rho32	0,37***	0,35***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho31	0,31 ***	0,25***		Rho42	0,30***	0,55***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho41	0,35 ***	0,49***		Rho43	0,45***	0,45***		
	(0,00)	(0,00			(0,00)	(0,00)		

Appendix 8: España

Innovation	Product		Process		Organizational		Marketing	
Variable	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3
Age (ln)	0,055	0,056	0,12 ***	0,13***	0,02	0,02	0,12 ***	0,10***
	(0,11)	(0,11)	(0,00)	(0,00)	(0,37)	(0,47)	(0,00)	(0,00)
Qual. Employment	0,002 ***	0,002***	-0,00006	0,0007	0,004 ***	0,004***	0,001 ***	0,001***
	(0,00)	(0,00)	(0,91)	(0,29)	(0,00)	(0,00)	(0,00)	(0,00)
Small	0,34 ***	0,33***	0,58 **	0,50***	0,34 **	0,33*	0,23 ***	0,19***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,08)	(0,00)	(0,00)
Medium	0,48 ***	0,47***	0,81 ***	0,73***	0,68 ***	0,67***	0,36	0,31***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Large	0,58 ***	0,56***	1,04 ***	1,00***	0,98 ***	0,98***	0,55 ***	0,54***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Export	0,31 ***	0,31***	0,105 *	0,15***	0,007	0,07**	0,19	0,19***
	(0,00)	(0,00)	(0,03)	(0,00)	(0,80)	(0,02)	(0,00)	(0,00)
Group	0,06 *	0,06*	0,16	0,09	0,005	0,032	-0,057	-0,05*
	(0,08)	(0,09)	(0,13)	(0,48)	(0,10)	(0,34)	(0,11)	(0,09)
Ln (R+D)	0,19 ***	0,19***	0,15 ***	0,15***	0,095 ***	0,09***	0,1 ***	0,1***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Org		0,06		-0,02				
		(0,78)		(0,93)				
Mk		-0,03		-0,87***				
		(0,85)		(0,00)				
rho21	0,33 ***	0,38***		Rho32	0,48 ***	0,60***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho31	0,25 ***	0,22***		Rho42	0,35 ***	0,84***		
	(0,00)	(0,00)			(0,00)	(0,00)		
rho41	0,33 ***	0,34***		Rho43	0,59 ***	0,59***		
	(0,00)	(0,00)			(0,00)	(0,00)		

Appendix 9: Colombia Manufacturas

Innovation	Product		Process		Organizational		Marketing	
Variable	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3
Qual. Employment	0,48 *** (0,00)	0,50*** (0,00)	-0,06 (0,58)	0,16 (0,88)	0,44 *** (0,00)	0,42** (0,01)	0,42 *** (0,00)	0,41*** (0,00)
Small	0, 25 * (0,05)	0,26*** (0,04)	0,12 (0,25)	0,13 (0,21)	0,16 (0,28)	0,17 (0,24)	0,09 *** (0,44)	0,09 (0,45)
Medum	0,50 *** (0,00)	0,52*** (0,00)	0,45 *** (0,00)	0,48*** (0,00)	0,52 *** (0,00)	0,53** (0,00)	0,30 *** (0,01)	0,29** (0,01)
Large	0,56 *** (0,00)	0,59*** (0,00)	0,5 *** (0,00)	0,55*** (0,00)	0,53 (0,99)	0,52*** (0,00)	0,45 *** (0,00)	0,44*** (0,00)
Export	0,19 *** (0,00)	0,18*** (0,00)	-0,02 (0,70)	-0,02 (0,68)	0,0001 *** (0,00)	0,01 (0,86)	0,03 (0,55)	0,03 (0,52)
Group	0,47 *** (0,00)	0,51*** (0,00)	0,28 *** (0,00)	0,33 (0,00)	0,40 *** (0,00)	0,40*** (0,00)	0,19 ** (0,03)	0,19** (0,03)
Ln (R+D)	0,24 *** (0,00)	0,25*** (0,00)	0,26 *** (0,00)	0,27*** (0,00)	0,18 *** (0,00)	0,18*** (0,00)	0,16 *** (0,00)	0,17*** (0,00)
Org		-0,44** (0,01)		-0,44*** (0,01)				
Mk		-0,003 (0,98)		0,26 (0,12)				
rho21	0,22 *** (0,00)	0,31*** (0,00)		Rho32	0,36*** (0,00)	0,58*** (0,00)		
rho31	0,28 *** (0,00)	0,48*** (0,00)		Rho42	0,31*** (0,00)	0,47*** (0,00)		
rho41	0,31 *** (0,00)	0,34*** (0,00)		Rho43	0,43*** (0,00)	0,42*** (0,00)		

Appendix 10: Colombia Servicios

Innovation	Product		Process		Organizational		Marketing	
Variable	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3	Eq. 2	Eq. 3
Qual. Employment	1,01 *** (0,00)	0,90*** (0,00)	-0,016 (0,82)	-0,029 (0,67)	0,10 (0,12)	0,11 (0,10)	-0,27 *** (0,00)	-0,25 *** (0,00)
Small	0, 32 * (0,09)	0,31* (0,09)	0,12 (0,49)	0,11 (0,51)	0,17 (0,36)	0,17 (0,33)	-0,01 (0,90)	-0,02 (0,89)
Medium	0,55 *** (0,00)	0,60*** (0,00)	0,37 ** (0,02)	0,41*** (0,00)	0,56 *** (0,00)	0,54*** (0,00)	0,19 (0,19)	0,18 (0,20)
Large	0,89 *** (0,00)	0,95*** (0,00)	0,66 *** (0,00)	0,70*** (0,00)	0,73 *** (0,00)	0,73*** (0,00)	0,24 (0,10)	0,23 (0,11)
Export	-0,002 (0,97)	0,01 (0,84)	-0,003 (0,96)	0,01 (0,86)	0,02 (0,71)	0,01 (0,85)	0,05 (0,46)	0,03 (0,61)
Group	0,37 *** (0,00)	0,42*** (0,00)	0,12 * (0,07)	0,18*** (0,00)	0,29 *** (0,00)	0,29*** (0,00)	0,16 ** (0,01)	0,16 ** (0,01)
Ln(R+D)	0,20 *** (0,00)	0,24*** (0,00)	0,21 *** (0,00)	0,24*** (0,00)	0,21 *** (0,00)	0,22*** (0,00)	0,18 *** (0,00)	0,19*** (0,00)
Org		-0,72*** (0,00)		-0,46** (0,01)				
Mk		-0,28 (0,12)		-0,45** (0,02)				
rho21	0,16 *** (0,00)	0,39*** (0,00)		Rho32	0,34*** (0,00)	0,61*** (0,00)		
rho31	0,19*** (0,00)	0,61*** (0,00)		Rho42	0,30*** (0,00)	0,57*** (0,00)		
rho41	0,16 *** (0,00)	0,37*** (0,00)		Rho43	0,32*** (0,00)	0,32*** (0,00)		

In the probit models age shows in Ecuador it has a negative and significant effect on the organizational innovation decision, but in Spain, the effect is positive and significant in the development of process and marketing innovations.

Qualified employees positively and significantly affect the firms' innovation decision, but with different effects between countries. In Ecuador, it is relevant in the 4 types of innovation, while in Spain and Colombia manufacturing does not show a significant effect in process innovation. For Colombian firms in services, it is only significant in product and marketing, while in Chile only for organizational innovation.

In Ecuador and Spain, all firms show a positive and significant effect on the decision of the four types of innovation. In the case of Chilean firms, small and medium-sized firms decide for product, process, and organizational innovation, but large firms decide for all four types of innovation. In the case of small firms in Colombia, manufacturing firms decide only for product and marketing innovation, while medium-sized firms decide for all four types of innovation, and large firms decide only for the product, process, and marketing innovation. In the case of small firms in Colombia Services decide for product innovation, while medium and large firms decide for the product, process, and organizational innovation.

For the firm environment, the effects are more specific. For the exporting firm characteristic, Chilean firms choose product and marketing innovation but do not choose process and marketing innovation. Contrary to what happens with Spanish firms, where it has a positive effect on the 4 types of innovation. In Colombia, the positive effect is in product innovation. On the other hand, belonging to a group of companies has a positive effect on the 4 types of innovation of the Colombian firms in manufacturing and services; while in Chile the positive effect is in organizational and marketing innovation.

When we look at the results of including non-technological innovations as inputs to product or process innovations, the results show that in all countries their effects are negative and significant. In Chile, marketing innovation has a negative effect on product innovation, while in Ecuador, Spain, and Colombia Services marketing innovation has a negative effect on process innovation. Finally, the results show that in

Colombia Manufacturing and Services organizational innovation has a negative effect on both technological innovations.

Appendix 11: results of percapita R&D expenditure equation

	Chile	Ecuador	España	Colombia manufacturas	Colombia servicios
Age	-0,068	-0,021	-0,025		
	(0,15)	(0,19)	(0,76)		
Qualifield employment	0,56 ***	0,25	0,019***	0,051***	0,65***
	(0,00)	(0,00)	(0,00)	(0,00)	(0,00)
Small	0,16*	-0,096**	1,02***	0,051	0,23 **
	(0,071)	(0,03)	(0,00)	(0,49)	(0,03)
Médium	0,44***	-0,15***	1,29***	0,43	0,42***
	(0,00)	(0,001)	(0,00)	(0,00)	(0,00)
Large	0,37***	-0,31***	0,64***	1,36***	0,96***
	(0,001)	(0,00)	(0,00)	(0,00)	(0,00)
Export	0,59 ***	0,10**	1,37***	0,22***	0,09
	(0,00)	(0,01)	(0,00)	(0,00)	(0,29)
Group	0,12	0,11**	0,10	1,03***	1,06***
	(0,10)	(0,00)	(0,20)	(0,00)	(0,00)
manufacturing	0,014	-0,08			
	(0,89)	(0,21)			
Service	-0,076	-0,28***			
	(0,44)	(0,00)			
patente	1,69	-0,005	1,57***	0,17	0,47*
	(0,00)	(0,89)	(0,00)	(0,48)	(0,09)
cooperation	3,89***	0,13**	2,73***	1,35***	1,83***

	(0,00)	(0,01)	(0,00)	(0,00)	(0,00)
Market information sources	0,39***	-0,31***		1,64***	1,7***
	(0,00)	(0,00)		(0,00)	(0,00)
Institutional information sources	-0,31**	0,38***		0,79***	0,30***
	(0,012)	(0,00)		(0,00)	(0,00)
Other sources	0,39***	0,10**		1,84***	1,33***
	(0,00)	(0,03)		(0,00)	(0,00)
Public finance			3,02***		
			(0,00)		

To discuss the choice of instruments, first, we estimate the r&d expenditure function (equation 1') using only one of the instrumental variables in the explanatory variables (thus, we have one equation for each instrumental variable included). The objective of these estimations is to analyze if there are changes in the F-test since one way to analyze if the instruments are weak is when F is less than 10.

The table below presents in the first column the value of the F-test when all instrumental variables are included in the same equation; and then in columns 2 to 5 the F-test when only one instrumental variable is included.

	All variable	Patent	Cooperation	Information	Public funding
Chile	132	54	**152**	72	
Ecuador	437	54	485	**487**	
España	641	302	**572**		604
Colombia Manufacturas	672	338	613	**788**	
Colombia Servicos	618	350	608	**684**	

Second, we estimate the predicted value of R&D expenditure using only one instrumental variable. The decision is to use the variable with the highest F-test value among columns 2-5 for each country. With these estimates we analyze whether the results of the multinomial logit model show changes with respect to the use of all the instrumental variables defined in Annex 11.

For Chile, three changes in the variables measuring firm size are presented. In particular for medium-sized firms there is now a positive and significant effect for three semi-complex and complex innovation strategies.

For Spain the main change is that the variables age, skilled employees and firm size positively and significantly affect the probability of choosing a complex strategy.

While in the results for Colombian firms there are no relevant changes in the previous results for significant variables.

CHAPTER 3: INNOVATION EFFORT BETWEEN R&D AND NON-R&D ACTIVITIES

4.1 Abstract

Not all innovation performance is explained by R&D spending. Given weak internal capabilities or resource constraints, many companies acquire knowledge from external sources to perform innovations. The literature differentiates these external knowledge acquisition activities as non-R&D. In this paper, we extend the discussion of innovation spending and analyze the intensity of spending that innovative firms (technological and non-technological) perform between R&D and non-R&D activities simultaneously. We use a discrete-continuous extreme value multiple models (MDECV) with firm-level information from innovation surveys in Chile, Ecuador, and Spain. The results show that in Chile and Ecuador, firms prefer non-R&D activities to R&D activities, in contrast to Spain, where (internal) R&D activities are the most preferred. In terms of firm´s characteristics, large companies in Spain and those belonging to groups of companies in Chile and Spain are more likely to use external R&D than internal.

Keywords: innovation activities, discrete-continuos model, non-R&D

Jel classification: O31, O32, O36, L20.

4.2 Introduction

The ability of firms to innovate lies not only in the development of internal R&D. The ability to acquire external knowledge and use it appropriately to develop innovations is also essential to perform innovations (Cassiman and Veugelers, 2006; Veugelers and Cassiman, 1999). The literature calls them non-R&D innovations. Non-R&D activities involve the acquisition of existing knowledge or technologies for innovation.

In this paper, we extend the discussion of innovation spending by analyzing the intensity of spending that innovative firms (technological and non-technological) perform using both R&D and non-R&D activities simultaneously. We also analyze how internal and external firms´ characteristics affect spending intensity on various R&D and non-R&D activities. This discussion is relevant because most literature focuses on R&D expenditure as the primary driver of innovation (Arundel et al., 2007; Barge-Gil et al., 2011; Hervas-Oliver et al., 2021). R&D expenditure is relevant for developing innovations, and academics have widely discussed this as part of the design of public policies (Banerjee and Gupta, 2021). Nevertheless, R&D spending carries much uncertainty in its potential to generate results. It requires fixed costs and specialized assets, becoming a limitation for the development of innovation in small firms or those that participate in low-technology markets compared to large firms or those that compete in high-technology markets (Moilanen et al., 2014; Rammer et al., 2009).

However, R&D is not the only driver for the development of innovations since the possibility of acquiring knowledge in the market allows companies to develop innovations and thus substitute the generation of knowledge by purchasing knowledge. There are other forms of knowledge acquisition that firms can carry out, such as the purchase of patents, employee training, or the acquisition of machinery, which allow firms to innovate (Arundel et al., 2007; Huang et al., 2010; Lee and Walsh, 2016; Thomä and Zimmermann, 2020) also in line with the proposed definition Chesbrough (2003) of open innovation whereby firms capture knowledge from the environment. Indeed, 73% of innovative firms in Chile, 76% in Ecuador, and 39% in Spain do not carry out R&D activities. However, this does not necessarily mean they do not innovate.

The literature has already recognized that firms can develop innovations by generating knowledge or purchasing knowledge, reducing innovation limitations (Barge-Gil et al., 2011). Knowledge generation involves the development of activities associated with R&D expenditure (internal or external), while purchasing involves the acquisition of existing knowledge (e.g., patents, software, equipment)(Jensen et al., 2007; Veugelers and Cassiman, 1999) involving the stages of obtain, integration, commercialization and interaction with the environment (West and Bogers, 2014).This paper contributes to filling the gap in the understanding of non-R&D innovations. The literature has focused on analyzing innovation decisions concerning whether or not they perform R&D or the intensity of R&D spending. However, there is scarce literature on non-R&D

activities such as purchasing software or machinery and training employees, among others (Arbussà and Coenders, 2007; Arundel et al., 2007; Cassiman and Veugelers, 2006; García-Quevedo et al., 2014). This thin literature has analyzed whether or not firms engage in non-R&D activities (dichotomic decision) or are more likely to do or mix these activities using pure discrete choice models. They have also emphasized product and process innovation decisions (Cassiman and Veugelers, 2006), ignoring non-technological innovations (organizational and marketing), which involve low R&D expenditure intensity (Trigo, 2013).

This paper aims to discuss how innovative firms allocate spending among different R&D activities and their preferences by type of spending, R&D versus Non-R&D. In this work, we answer the question of how firms' capabilities affect the decision to spend on R&D and Non-R&D activities.

This study contributes to the current literature in several areas. First, we discuss the relevance of spending R&D and Non-R&D activities of all innovative firms, technological and non-technological, and we include firms involved in agriculture, manufacturing, and services and we analyze how open innovation activities relate to the firm's R&D activities. Second, we use the intensity of spending on R&D activities as a dependent variable instead of previous analyses that use a discrete choice dependent variable (yes/no). In addition, we perform a significant methodological innovation by using a multiple discrete-continuous extreme value model (MDCEV) that allows us to analyze discrete (yes/no) and continuous (intensity) firms' choices between R&D and non-R&D activities. Innovation studies traditionally use R&D (internal and external) expenditure as a determinant of innovation decisions. However, there are other knowledge acquisition (Non-R&D activities) options such as employee training, software acquisition, patents, machinery or market activities that also allow innovation. For this reason, we use the intensity of spending by firms on different innovation activities.

We use data from three contrasting countries; Ecuador, Chile, and Spain. Ecuador is a developing country, while Chile and Spain are high-income countries (Real, 2022) members of the OCDE. However, Chile has just recently inter to the list of high-income countries and can be considered the middle ground between Ecuador and Spain. By including these countries, we aim to determine whether there are differences in the choice of firms according to the context of the firms and the development of the markets in which they compete.

Our results show that firms prefer to invest in non-R&D activities over internal R&D spending in both Chile and Ecuador. In contrast, firms' preferences are for internal R&D investment in Spain. While medium and large firms that participate in external markets and have skilled employees are less likely to invest in non-R&D activities, particularly marketing activities and acquisition of machinery and equipment.

4.3 Literature review

R&D expenditure is the primary driver of innovation discussed in the literature, mainly due to its evident relationship with the generation of knowledge and productivity of firms (Lee and Walsh, 2016; Rammer et al., 2009). It has been part of the academic debate and public policy design (Alam et al., 2019; Arundel et al., 2007; Barge-Gil et al., 2011; Huang et al., 2010; Rammer et al., 2009; Xie et al., 2019). This discussion has left in the background other options of innovation activities that also imply knowledge generation for firms and that have an effect on the development of innovations (Arbussà and Coenders, 2007; Moilanen et al., 2014). Huang et al. (2010) and (Arundel et al., 2007) indicate that firm-level innovations depend not just on spending on specific internal or external R&D activities, o as proposed by Chesbrough (2003) open innovation allows firms to integrate external ideas to complement internal ideas and advance their technology. It can also occur by imitating activities, adopting consumer innovations, or combining existing knowledge through various means such as industrial or process design. These so-called non-R&D activities are a source of relevant knowledge, such as training employees for innovation, acquiring specific patents or software, or acquiring technology, especially for small and low-tech firms. In other words, although a firm does not generate its own knowledge, it can acquire it and develop innovations (Choi and Lee, 2018; Zuniga and Crespi, 2013).

Empirical evidence has discussed the importance of R&D expenditure because it increases the knowledge stock of firms and allows the creation of new products or processes (Doloreux et al., 2016; Huang et al., 2010). It argues that R&D is an important element of the capacity to acquire external knowledge and transform it into innovations, known as absorptive capacity (Huang et al., 2010). Thus, firms that develop R&D have more outstanding innovation capabilities than firms that do not spend on R&D.

Nevertheless, internal R&D efforts imply costs and risks of the decision due to the need to allocate resources for the implementation of laboratories and equipment, high fixed costs, and time needed to obtain results (Barge-Gil et al., 2011; Doloreux et al., 2016; Rammer et al., 2009). This effort implies financial and resource needs that only large firms can afford and can diversify risk in several projects and use the economies of scale of R&D spending (Huang et al., 2010; Thomä and Zimmermann, 2020). Whereas medium and small firms are less likely to spend on R&D due to resource restrictions, high fixed costs, financing restrictions, human resources, and weakness in the appropriability of the benefits of innovations (weak innovation capabilities) (González et al., 2016; Ortega-Argilés et al., 2009; Rammer et al., 2009).

However, not all innovations occur with R&D spending. This implies that the innovation process is not necessarily linear, as traditionally discussed, where internal R&D spending generates knowledge to obtain innovations (Hervas-Oliver et al., 2021; Santamaría et al., 2009). This view has neglected other sources of innovation such as the adoption and adaptation of processes for the development of innovations. In the transaction cost theory view, these mechanisms refer to acquiring knowledge in a market and allowing firms to substitute internal investment in R&D expenditure with external knowledge acquisition (Cassiman and Veugelers, 2006; Santamaría et al., 2009).

Firms that innovate can generate or acquire knowledge (Arundel et al., 2007; Moilanen et al., 2014), which Veugelers and Cassiman (1999) define as making or buying. Making knowledge is when the firm spends on internal or external R&D, while buying is when firms acquire external knowledge such as patent acquisition, training, machinery, or software comparisons. Innovation can occur by generating knowledge within the firm or exploiting existing knowledge (Arundel et al., 2007; Barge-Gil et al., 2011; Hervas-Oliver et al., 2014; Huang et al., 2010; Trigo, 2013). Jensen et al. (2007) define that knowledge generation can occur through a process called science, technology, and innovation (STI) which is associated with formal internal R&D processes, or through doing, using, and interacting (DUI), which comes from non-formal processes of learning and experience. Therefore, we can indicate that making knowledge implies the development of STI activities while buying implies DUI activities (Parrilli and Radicic, 2021) from the open innovation view, the acquisition of knowledge for innovation occurs through the interaction of companies with suppliers, customers, competitors, public or private institutions (Satanko et al, 2017; west and bogers, 2014).

Given the heterogeneity among innovating firms and their capabilities for innovation (Choi and Lee, 2018; Parrilli and Radicic, 2021), internal knowledge generation is more associated in firms that develop product innovations or competing in high-tech industries, where the decision involves long-term activities and a higher innovation capacity to support investments in fixed costs associated with R&D spending (Hervas-Oliver et al., 2011; Huang et al., 2010; Lee and Walsh, 2016).

The decision to buy knowledge is associated with the process innovation decision in low and medium technology industries, where learning occurs by learning by doing, and which is a more short-term activity because it requires less scientific infrastructure and less use of resources (Hervas-Oliver et al., 2011; Hervas-Oliver et al., 2014; Ortega-Argilés et al., 2009; Santamaría et al., 2009; Zuniga and Crespi, 2013). Therefore, firms' innovation activities may vary considerably on the nature and technological level of the firm's activities, the degree of consumer involvement, the stage of the product life cycle, and the intensity of human capital participation in the innovation process (Lee and Walsh, 2016; Santamaría et al., 2009).

A relevant source of discussion has been the relationship between the size of firms and the probability of performing R&D activities (Choi and Lee, 2018). The financing needs for the development of R&D activities imply more options for large firms. Santarelli and Sterlacchini (1990) indicate that large firms have more incentives to use formal innovation activities and R&D expenditures, and small firms have incentives to use informal R&D activities, asset acquisition, design, or industrialization. Rothwell and Dodgson (1991) analyze the advantages and disadvantages of firms according to their size to develop internal and external innovation activities. Small firms have certain advantages that allow them to innovate. For example, they are more flexible in adapting to customer needs, leading them to innovate more in terms of products (Hervas-Oliver et al., 2011). Medium and small firms are also less bureaucratic, and due to greater administrative control, the acquisition of external knowledge can be faster and be used to develop innovations (Thomä and Zimmermann, 2020) and can communicate faster with the environment for the acquisition of technologies and knowledge, even more so today with the availability of platforms for innovation, social media, incubators, living labs, among others (Hossain and Kauranen, 2016; Stanko et al., 2017). These characteristics imply a greater probability that large firms will develop internal and external R&D spending, while small firms will acquire knowledge by spending on non-R&D activities (Hervas-Oliver et al., 2021; Rothwell and Dodgson, 1991; Santarelli and Sterlacchini, 1990). Hossain and Kauranen (2016) indicates that large firms develop internal R&D, while medium and small firms interact with the environment to acquire and exploit knowledge but do not have the capacity to carry out a very extensive search.

Another constraint for the development of internal R&D is the internal capabilities that a firm needs, for example, the need for advanced human capital in terms of experience and training (Arundel et al., 2007; González et al., 2016; Protogerou et al., 2017). This weakness in innovation capabilities is associated with small firms and with firms that compete in domestic markets (that do not develop exports). They have low levels of tertiary education among their workers, which makes them dependent on the provision of external knowledge (Hervas-Oliver et al., 2015; Huang et al., 2010; Moilanen et al., 2014; Tamayo and Huergo, 2017). Hervas-Oliver et al. (2021) show that these firms are more likely to use non-R&D activities and that they would innovate in products. Xie et al. (2019) state that these firms can adapt external knowledge through learning-by-doing, substituting the risks and costs of formal R&D activities with management techniques. Moilanen et al. (2014) and Trigo (2013) associate these low capabilities with medium and low-tech competing firms where innovations are more concentrated in incremental modifications or changes, design, and optimization, which implies less intensity of R&D expenditure.

Furthermore, given that the development of innovations implies internal capabilities for innovation, the discussion should not be centered exclusively on the option of making or buying alternatives or on internal versus external efforts. It is also possible that there exists a combination of both forms of knowledge acquisition (González et al., 2016; Stieglitz and Heine, 2007; Xie et al., 2019), due to the existence of complementarity between the absorptive capacity that firms develop and the acquisition and assimilation of external knowledge. Cassiman and Veugelers (2006) show, using a multinomial logit model (pure discrete choice model), that large firms are more likely to combine knowledge by making and purchasing. Moilanen et al. (2014) also indicate that there is complementarity between internal R&D and non-R&D activities that is relevant in small firms because it allows them to development absorptive capacity. Finally, Santamaría et al. (2009) argue that combining internal and external knowledge sources is critical for competitive advantage.

Other relevant issue is that the discussion of spending on R&D activities has focused on the development of technological innovations (product and process innovations) in the manufacturing industries (Arbussà and Coenders, 2007; Barge-Gil et al., 2011; García-Quevedo et al., 2014; Parrilli and Radicic, 2021). Nevertheless, firms that compete in low-tech industries tend to acquire knowledge through non-R&D activities. In these cases, innovations tend to concentrate in organizational processes and marketing compared to firms that compete at the technological frontier (Guo et al., 2017; Hervas-Oliver et al., 2011; Hervas-Oliver et al., 2021). Therefore, excluding non-technological innovations implies a bias in the discussion (Doloreux et al., 2016; Ortega-Argilés et al., 2009; Santamaría et al., 2009). For example, service firms predominate in non-technological innovations and therefore have low R&D intensity (Trigo, 2013; Xie et al., 2019), which implies that innovations come from other sources of knowledge (Gallouj and Savona, 2009; Santamaría et al., 2009).

In conclusions, in the development of innovations, firms can achieve them not only by developing R&D activities but also by acquiring knowledge through non R&D activities and even by combining them (Dai et al., 2020; Hervas-Oliver et al., 2014; Stieglitz and Heine, 2007). Therefore, firms should emphasize the acquisition of knowledge from both sources (Arbussà and Coenders, 2007; Parrilli and Radicic, 2021). And extend the discussion from how non-R&D activities are innovation inputs to analyzing how firm and environmental characteristics affect the intensity of firm spending between R&D and non-R&D activities (Choi and Lee, 2018; Dai et al., 2020). Firms should develop open innovation as it allows them to interact with the environment to acquire and exploit knowledge, develop collaborative practices, improve R&D procedures, and access commercialization networks for their products, even more so for small firms or those in early stages of innovation (Hossain and Kauranen, 2016; Stanko et al., 2017).

4.4 Data and Metdodology

4.4.1 Data y sample

We use innovation surveys from 3 countries: Chile, Ecuador, and Spain. For Chile, we use the survey from 2015-2016. For Ecuador, we use the survey of science, technology, and innovation activities from 2012-2014, while in the case of Spain, we use the company innovation survey from 2016. These surveys follow the guidelines of the Oslo Manual. They provide information on the characteristics of the companies and allow us to analyze the development of products, processes, organizational and marketing innovations.

We defined five variables to compare and analyze the intensity of spending on innovation activities between countries. Two are related to R&D activities, internal R&D, and external r&d; and the other three are related to non-innovation activities, knowledge for innovation, market, and machinery and equipment. Each country develops the innovation survey under the guidelines of the Oslo manual. However, the extent and name of the so-called non R&D activities differs between countries. Given this, we have made a grouping of the activities in order to work with only 5 innovation activities. This classification is shown in table 3.1 by category, according to the grouping we made of the questions provided by each country in their respective questionnaires.

Table 3.1: Innovation activities

	Variable	Chile	Ecuador	España
R&D activities	Internal r&d External r&d	Interna r&d External r&d	Internal r&d External r&d	Internal r&d External r&d
Non R&D activities	knowledge for innovation	External knowledge acquisition. Innovation training.	Contracting of consulting and technical assistance. Staff training. Acquisition of deincorporated technology.	Acquisition of other external knowledge. Innovation activities training.
	Market	Introduction of innovations to the market. Design.	Market studies. Engineering and industrial design activities.	Introduction of innovation to the market Design, other preparations for production and marketing.
	machinery and equipment	Acquisition of machinery, equipment, software and buildings. Installation and commissioning of new equipment.	Acquisition of machinery and equipmen.t Hardware acquisition. Software acquisition.	Acquisition of machinery, equipment, software and buildings

Table 3.2 shows the distribution of firms between R&D and non R&D activities. We can see that in Chile and Ecuador, more than 70% of innovative firms do not carry out R&D activities, while in Spain, 66% do not carry out non R&D activities. Regarding the firms that carry out R&D activities, in all three countries, a more significant proportion carry out only one activity. While in the case of the

development of non R&D activities in Chile (48%) and Spain (22%) a higher proportion of firms develop only one activity, in Ecuador, the highest proportion is between 1 (26%) and 2 (21%). As indicated by Hossain and Kauranen (2016) firms do not have the capacity to search extensively for external information.

Table 3.2: Firms by type of innovation activities (in parenthesis n° of innovative firms)

	Chile (n = 1380)		Ecuador (n = 4557)		España (n = 4668)	
Activities	R&D	Non-R&D	R&D	Non-R&D	R&D	Non-R&D
0	73%	28%	76%	49%	39%	66%
1	22%	48%	21%	26%	43%	22%
2	5%	19%	3%	21%	18%	9%
3		5%		4%		3%

4.4.2 Explanatory variables

We included the set of explanatory variables defined among groups of firm characteristics and traditionally used in studies of innovation-decision determinants in the three decision models. Table 4 shows the descriptive statistic for the variable. The first group of variables aims to characterize the firm: *Age of the firm,* calculated as the difference between survey´s year and firms´ creation. This variable represents the learning process over time that allows accumulating knowledge and experience during the life cycle. *Skilled employees* is the percentage of a firm's workers with higher education. It is used as a proxy of the firm's absorptive capacity to represent the possibility of acquiring knowledge. *Firm size*, which is the number of employees characterized by intervals of workers differentiating among micro, small, medium, and large firms, represents the 'firm's access to resources that allow the development of specific innovations or the possibility of accessing economies of scale or scope. The development of R&D activities is incorporated as the variable *R&D expenditure,* which is the per capita expenditure on all R&D activities and represents the firm's efforts to generate internal and external knowledge to develop innovations.

The second group of variables measures the effects of the environment on the firm's decisions. Export is a dichotomous variable that takes the value 1 for a firm participating in external markets. More competitive markets are expected to affect the development of innovations to adapt to the characteristics sought by consumers. *Group* characterizes whether or not the firm belongs to a group of companies (dichotomous variable). Belonging to a bigger group allows the company to access more information from the different markets in which they participate. Therefore, it enables them to develop innovations in a cross-cutting manner among the companies to take advantage of economies of scope.

Finally, the third group of variables controls the firm's economic activity. We use dichotomous variables to indicate whether firms belong to the agricultural, manufacturing, or service sectors.

4.4.3 Statistical model and explanatory variable

We are interested in analyzing the intensity of spending by firms on R&D and non-R&D activities. Table 3.3 shows the average expenditure by type of activity of innovative firms in each country. In table 3.4 the explanatory variables are presented.

Table 3.3: Average spending (US$)

	Internal R&D	External R&D	Knowledge for innovation	Market	Machinery and equipment
Chile	245,30	21,21	16,22	17,63	259,28
España	60521,63	21137,23	6838,83	11277,91	18509,63
Ecuador	16,67	4,02	16,12	17,22	133,89

Spending behavior shows that Spain has a higher average expenditure than Chile and Ecuador in all innovation activities. And while in Spain the highest average expenditures occur in internal R&D together with machinery and equipment, in Chile and Ecuador this last activity is the most relevant.

Table 3.4: Descriptive statistics

Variable	Description	Chile	España	Ecuador
Innovated	Dummy=1 if firms developed some innovations	0,23	0,6	0,56
		(0,42)	(0,48)	(0,49)
Firms´s Characteristics				
age	Years of the firm since its creation	20,4	33,2	18,09
		(15,19)	(20,8)	(14,18)
Qualifield employment	Percentaje of employess with tertiary education, mastrer and doctorate	0,41	0,29	0,30
		(0,36)	(0,29)	(0,27)
Micro	Dummy = 1 when firm has employees <11	0,28	0,14	0,09
		(0,45)	(0,34)	(0,29)
Small	Dummy = 1 when firm has 11 <= employees <26	0,20	0,16	0,38
		(0,4)	(0,37)	(0,48)
Medium	Dummy = 1 when firm has 26 <= employees < 201	0,36	0,41	0,39
		(0,48)	(0,49)	(0,48)
Large	Dummy = 1 when firm has employees =>201	0,14	0,27	0,12
		(0,35)	(0,44)	(0,32)
Spending in R&D activities	Per capita spending on R+D	533,66	7786,22	3090,2
		(3723,43)	(114326,7)	(132625,5)
Firm´s EnvIronment				
Export	Dummy = 1 if firm export.	0,12	0,47	0,12
		(0,33)	(0,49)	(0,33)
Group	Dummy = 1 if firm belongs to group.	0,12	0,46	0,17
		(0,00)	(0,49)	(0,38)
Economic Activity				

Agricultural	Dummy = 1 if the firm belongs to the agricultural sector.	0,13 (0,33)	0,03 (0,19)
manufacturing	Dummy = 1 if the firm belongs to the manufacturing sector.	0,31 (0,46)	0,25 (0,45)
Service	Dummy = 1 if the firm belongs to the service sector.	0,56 (0,56)	0,70 (0,45)

To improve the understanding of decisions to innovate and the intensity of spending on R&D and non-R&D activities, we propose to use a generalized corner solution approach, known as the Kuhn-Tucker model or the multiple discrete-continuous extreme value (MDCEV) model. This model explains the firm's choice among several options it faces simultaneously (Lu et al., 2017). These options are imperfect substitutes for each other (Acharya and Marhold, 2019; Bhat, 2005). This model is based on the implementation of a stochastic process of maximization of a utility function facing the choice of alternatives that can occur simultaneously, which considers the existence of non-innovation and innovations under the existence of diminishing marginal productivity in production (Bhat, 2005). In particular, when we have some alternative that is always chosen, then the model considers an "external good."

This model assumes an additively separable utility function that has as an argument the number of innovations of each k type (x_k) that could also be zero. The functional form is the following:

$$U(t) = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k} \varphi(x_k) \left\{ \left(\frac{x_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right\} \quad (1)$$

In which φ corresponds to the baseline utility, and it is defined as positive, that is $\varphi(x_k) = \exp(\beta' z_k + \varepsilon_k)$, where $\beta' z_k$ indicates the alternative's baseline utility and the term ε_k is i.i.d. random disturbance following a $Gumbell(0, \sigma)$ distribution. The marginal rate of substitution between two types of innovation can be expressed by the ratio of their respective baselines utilities $\varphi(x_k)$. α_k is a satiation parameter representing the diminishing marginal of utility, γ_k is a translation parameter (also involved in the level of satiation) and capture possible corner solutions and x_k, as we stated before, is the quantity of innovations of type k. Moreover, $\varphi > 0, \gamma_k > 0$ y $\alpha_k \leq 1$. The firms maximize their utilities subject to a budget constraint, that in this case is given by the total number of innovations that they can develop, multiplied by the cost p of them:

$$\sum_{k=1}^{K} p * x_k = E$$

Where E is the total expenditure (budget) in innovations.

This MDCEV specification can be estimated through the Lagrangian multiplier technique and the Kuhn Tucker first-order conditions. The Lagrangian can be expressed as follows:

$$\mathcal{L} = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k} \varphi(x_k) \left\{ \left(\frac{x_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right\} - \lambda \left[\sum_{k=1}^{K} p x_k - E \right], \quad (2)$$

where λ is the Lagrangian multiplier associated with the budget constraint. Then, the Kuhn Tucker first-order condition for the optimal innovations allocation (x_k^* values) is given by:

$$[\exp(\beta' z_k + \varepsilon_k)]\left\{\left(\frac{x_k^*}{\gamma_k} + 1\right)^{\alpha_k - 1} - 1\right\} - \lambda = 0 \;\; if \; x_k^* > 0, k = 1,2,3, \ldots, K$$

$$[\exp(\beta' z_k + \varepsilon_k)]\left\{\left(\frac{x_k^*}{\gamma_k} + 1\right)^{\alpha_k - 1} - 1\right\} - \lambda < 0 \;\; if \; x_k^* = 0, k = 1,2,3, \ldots, K$$

Bhat (2008)mentions that the budget constraint implies that only $K - 1$ of the x_k^* values need to be estimated for identification purposes. To adapt this restriction, innovation in process is designated so that the firms allocate a non-zero amount of resources on this innovation. Thus, for the innovation in process, the Kuhn tucker first-order condition is as follows:

$$\lambda = [\exp(\beta' z_k + \varepsilon_k)]\left(\frac{x_k^*}{\gamma_k} + 1\right)^{\alpha_k - 1}$$

Substituting λ into equation (2), we can rewrite the Kuhn tucker conditions as:

$$V_k = \beta' z_k + (\alpha_k - 1)\ln(x_k + 1) \qquad (j = 1,2,3, \ldots, K)$$

Then, the probability of an observed vector of innovations is then given by:

$$P(x_1^*, x_2^*, \ldots, x_M^*, 0, \ldots 0) = \frac{1}{p_1}\frac{1}{\sigma^{M-1}}\left(\prod_{m=1}^{M} f_m\right)\left(\sum_{m=1}^{M}\frac{p_m}{f_m}\right)\left(\frac{\prod_{m=1}^{M} e^{V_i/\sigma}}{\left(\sum_{k=1}^{K} e^{W_k/\sigma}\right)^M}\right), (3)$$

where $f_i = \frac{1-\alpha_i}{x_i^* + \gamma_i}$, $W_k = \beta' z_k + (\alpha_k - 1)\ln(x_k + 1)$. As we do not use an outside good in this initial specification, the loglikelihood can be calculated using the probability showed in equation 3.

To sum up, through the estimation of this MDCEV model, we can get β baseline constant parameters, γ_k satiation parameters and the explanatory variables of each innovation decision.

4.5 Result and discussion

Tables 3.5 show the results of the estimations for the baseline preferences by type of R&D or non-R&D activities, and table 3.6 shows the result of satiation parameters. Results for the parameters of the explanatory variables with respect to the R&D and Non-R&D spending options are presented in appendix. Internal R&D spending is considered the baseline alternative for the three countries analyzed. A series of variables describing firm and firm environment characteristics are then included to estimate their impact on preferences for other R&D and non-R&D activities.

Tabla 3.5: Result for decision between R&D and non-R&D activities.

Baseline Constans	Chile	Ecuador	España
R&D internal	Fixed	Fixed	Fixed
R&D External	4,79*	0,31	-3,09*
Knowledge and Innovation	6,18*	2,69*	-5,34*
Market	5,73*	-0,09	-2,52*

Machinery and equipment	11,45*	4,37*	-3,45*

The result of the parameters concerning the base alternative for Chile and Spain shows that the four types of innovation activities defined are statistically significant. However, only the non-R&D activities knowledge for innovation and machinery and equipment are statistically significant in Ecuador. While for the results of the gamma parameters in the three countries, the results are statistically significant. Regarding the explanatory variables of the decision by type of R&D or non-R&D activity, results show differences between countries, both in significance and signs. Table 3.7 shows a summary of the sign of the parameter by country and type of activity, only in those cases where the results are statistically significant.

Tabla 3.6: Result for Gamma satiation parameters

	Chile	Ecuador	España
R&D internal	2,2*	0,32*	24,43*
R&D external	0,49*	0,55*	3,04*
Knowledge and innovation	0,09*	0,12*	0,32*
Market	0,10*	0,37*	1,48*
Machinery and equipment	1,11*	1,22*	8,14*

For the particular case of Chile and Ecuador, the positive sign of the rest of the activities implies that firms choose internal R&D spending as the last option. In both countries, firms first prefer non-R&D activities of acquiring machinery and equipment and then acquiring knowledge for innovation. Then for Chile, they would develop market activities for innovation and external R&D activities. This is the opposite of what happens in Spain since the most demanded activity is internal R&D expenditure and all other activities are less preferred. For innovative firms in Chile and Ecuador, we see that the acquisition and exploitation of knowledge, the initial phases of open innovation, is more relevant for firms. This allows them to obtain innovations from external sources and integrate these innovations into internal processes (West and Bogers, 2014).

Regarding the satiation parameters, in the three countries, the lowest gamma parameter is in the activity of knowledge for innovation, followed by the market and finally internal R&D expenditure for Chile and Ecuador. This lower value in the three countries implies that the satiation in the consumption of this activity is faster, given that in this type of activities we have actions that can be very specific for the development of innovations.

Tabla 3.7: Result summary

	R&D external			Knowledge for innovation			market			Machinery and equipment		
Country	Ch	Ec	Es	Ch	Ec	Es	Ch	Ec	Es	Ch	Ec	Es
Ln Age				-								
Qual. Employment							-			-	-	
Small												
Médium	-		+				-		-			
Large	-		+	-			-			-		
Export				-		-				-	-	-
Group	+		+			-						
Manuf	-	-			-			-			-	
Service	-	-					+	-				

Table 3.7 shows a summary of significant results by country (result of parameters by country are presented in the annex), we have differences in terms of significance and signs to explain the decision of the firms to develop or not one or several of the innovation activities with respect to internal R&D expenditure. For Ecuador and Chile, all the parameters that turn out to be significant have a negative sign except for one case for firms belonging to the service sector and development of market innovation activities. While in Spain we have a mix of positive and negative significant results. This is also related to the propositions of

open innovation where firms with restricted capabilities for innovation (resources, human capital, particular knowledge and unstructured) will use more external sources for innovation.

Given the results we have for the included parameters, we see that exporting firms are less likely to invest in knowledge activities for innovation and acquisition of machinery and equipment. This decision is based on the fact that this type of firm competes in foreign markets and must act quickly to adapt its products to the needs of local consumers, which the literature recognizes more with spending on R&D activities.

In the case of the economic activity developed by the firms, the results show that manufacturing and service firms are less likely to develop external R&D. In particular, manufacturing firms do not develop any non-R&D activities. This result, which is supported by the results from Chile, is conditioned by the activity of manufacturing firms more focused on product innovation and the relevance of this in internal R&D activities. While service firms are more likely to invest in non-market R&D activities, which is explained by the fact that these firms are more focused on developing non-technological innovations, which are of low R&D intensity.

For the results of the firm size effect, the results for Chile show that medium and large firms are less likely to develop external R&D or non-R&D activities, which is consistent with the literature that defines that these firms can develop more internal R&D activities due to the access to resources and financing for the development of innovations. While the case of Spain. Medium and large firms have a higher probability of spending on external R&D.

4.6 Conclusion

Although innovation performance is traditionally strongly associated with R&D spending, this relationship is not the only one that allows firms to innovate. This is because a number of firms do not engage in R&D activities but show unemployment in innovation. Despite this, the focus of analysis and policy development has been on R&D development.

One of the needs of firms is the generation of knowledge and capabilities to develop innovations. However, the discussion focused only on product and process innovation has biased the analysis, leaving aside the organizational and marketing innovation options associated with the development of non-R&D activities—also considering that in terms of performance, there are no differences between R&D and non-R&D firms.

On the other hand, complementarity in the generation of knowledge, especially in small and medium-sized companies, can occur through the acquisition of knowledge in the market and thus generate innovation, also in line with open innovation proposals where small or younger firms with more restrictions to innovate can access knowledge from external sources and integrate it for innovation and commercialization. In the case of Chilean and Ecuadorian firms, non-R&D activities are preferred for knowledge acquisition. This represents the limitations of firms in emerging markets in terms of access to financing and size and limits the development of internal R&D activities, while in Spain firms prefer the development of R&D activities over non-R&D activities. However, today in interactions with the market firms can access funding for innovations through platforms, social media or crowdfunding.

4.6.1 References

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	R&D External			Knoeledge for innovation			Market			Machiney and Equipment		
Country	CH	EC	ES	CH	EC	ES	CH	EC	ES	CH	EC	ES
LN age	-0.37	-0,15	010	-0,90*	0,14	0,60	-1,13	-0,21	019	-0,64	-0,10	0,28
Qual.	-0,450*	-0,29	-0,001	-2,40*	0,53	0,0009	-3,81*	0,79	-0005	-5,5*	-0,89*	-0,02
Employment												
Small	-1.84	0,23	0,46	-0,66	0,57	0,55	-1,46	0,28	-0,04	-1,37	0,18	0,20
Medium	-3,59	0,34	0,78*	-1,08	0,90	0,45	-3,68*	02,7	-0,58*	-2,16*	0,007	0,10
Large	-4,27*	-0,40	1,11	-2,74*	0,29	0,85	-5,88*	048	-0,05	-4,73*	0,72	0,71
Export	-0,03	-0,42	-0,07	-1,84*	-0,41	-0,60*	-0,57	-0,34	-0,24	-2,77*	-0,74*	-0,41
Group	1,39	0,08	0,56*	-0,90	0,58	-0,43*	-0,01	0,84*	-0,04	-0,18	0,47	-0,52
Manuf	2,20*	-3,37*		0,74	-2,81*		1,78	-2,06*		-0.56	-1,91*	
Service	2,07	-2,07*		1,01	-0,85		3,18*	-2,30*		-0,21	-1,13	

CONCLUSIONS

Firms decide to innovate within a set of options that combine technological and non-technological innovations, in order to make the best possible use of the resources they have available to develop innovations. The results show that the internal and external characteristics of the firm affect this decision, describing heterogeneous behaviors in the firms' decisions regarding which combinations of innovations to develop. According to the theoretical discussion that exists today, we can indicate that the best way to explain this decision is through complementarity in the joint development of innovation, and not necessarily considering that non-technological innovations are an input of technological innovations. This complementarity is more present between organizational and process innovations, and the best way to describe this process is by means of a multinomial probit model. We also observed heterogeneous behavior with respect to spending on innovation activities. When including R&D and non-R&D activities in the analysis, the results show that per capita spending on all activities is relevant to the probability of innovation. However, there are differences in the effort by type of expenditure made by firms in different countries. In the case of the Latin American countries considered in the paper, the results show that non R&D activities are more preferred, compared to Spain where internal and external R&D activities are more preferred among firms.