Barriers to innovation and willingness to innovate in the food sector: the case of Chile

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Abstract

Purpose – The goal of this research is to evaluate obstacles to innovation according to the perception of firms in the Chilean food sector, and to assess the relationships of these obstacles with innovation spending and willingness to innovate.

Design/methodology/approach – We analyzed data from the Chilean National Innovation Survey (Encuesta Nacional de Innovación) of 2017 and 2019, which were administered by the Ministry of Economy and the National Institute of Statistics. This survey is designed to be nationally representative. The methods we employed to analyze the data include linear regression, probit and logit models and factor analysis.

Findings – We found that obstacles to innovation can be grouped into five types, namely: cost-based, knowledge-related, market problems, lack of necessity for innovations and regulatory. Cost was positively, and significantly, associated with innovation (expenditures and willingness to innovate). We argue that this is because as firms engage in innovation, they become aware of the associated costs. Also, knowledge obstacles and lack of necessity were negatively associated with innovation. This may mean that as firms engage in innovation, they are able to overcome said obstacles; which speaks well of their innovation ecosystem.

Originality/value – We develop the argument that survey-based studies of obstacles are amenable to a perception-based interpretation of obstacles, because most surveys tend to collect firms' perceptions. Consequently, we provide perception-based explanations for our findings. Additionally, most empirical studies of obstacles in the food sector are of a qualitative nature. Our work supplements this literature with a quantitative analysis that can expand our understanding of innovation in the food industry.

Keywords Innovation, Innovation in the food sector, Innovation surveys, Obstacles to innovation, Willingness to innovate

Paper type Research paper

1. Introduction

By the year 2050, the world population is estimated to be 9,700 million people (FAO, 2018), the current world population is 6,000 million. Innovations in the food industry are key to solving the problem of feeding more people with limited natural resources. Therefore, studying what drives, spurs and/or hinders innovation in the food sector is of utmost importance. In particular, researchers have found a number of factors that may deter innovation, if not managed properly. The list includes: lack of necessary funding, absence of adequate collaboration networks, presence of strong barriers to entry, excess (or lack) of regulation, among others (Piperopoulos, 2007). These obstacles have been studied in different kinds of organizations and firms, ranging from small to large, and including most industry sectors,

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such as: manufacturing, financial, medical and high tech. Furthermore, studies have been carried out in several countries worldwide and employing a wide array of qualitative and quantitative methods (Tiwari and Buse, 2007; D'Este *et al.*, 2012). However, despite the fact that the study of barriers to innovation has aroused great interest in recent years (Pellegrino and Savona, 2017; Lars *et al.*, 2016), there is still not much literature specializing on studying them in the food sector, whether in agriculture, food manufacturing or other related industries. This work aims to contribute with an empirical study of innovation barriers in this sector.

A review of the literature on innovation obstacles allows us to identify two main dimensions among which pertinent works can be organized. The first dimension is related to the empirical method employed: quantitative or qualitative. The second dimension allows for organizing studies according to the underlying assumptions they make about what constitutes an obstacle. Some studies tend to view obstacles as external barriers, while others conceive them as inherently subjective and evolutionary. We argue that the second conceptualization is more amenable to studies of obstacles to innovation because data on obstacles is almost always based on perception. In particular, innovation surveys throughout the world tend to ask firms to assess barriers to innovation based on what they perceive.

The aim of this research is to evaluate obstacles to innovation according to the perception of firms in the Chilean food sector – a country with potential as global food supplier. Furthermore, we seek to study the relationship of these perception-based assessments of obstacles to two types of outcomes: innovation expenditures, and willingness to innovate. To this end, we carried out a quantitative study using data from two versions of the Chilean National Innovation Survey *(Encuesta Nacional de Innovation)* – 2017 and 2019. Our final sample contains 1,727 firms. Firstly, we ran a factor analysis to uncover latent factors representing the many types of obstacles that are asked in the survey. Secondly, we ran linear regressions to analyze the relationship between those factors and innovation spending. Finally, to assess whether this same set of obstacles can be associated to the decision to innovate (spend money on innovation or not), we employed logit and probit models.

The paper is structured as follows. Section 2 presents a review of relevant literature on obstacles to innovation and its relationship to the food sector. Section 3 discusses the methodology we employed; we present our data source and the quantitative analysis tools we used. Section 4 presents the main results of our study. And finally, Section 5 discusses our findings in relation to the literature on innovation and to the perception-based interpretation of obstacles; we conclude by providing some insight to policy makers and industry practitioners in the food sector.

2. Obstacles to innovation

2.1 Conceptualizations and methods to study obstacles

The study of barriers to innovation has aroused interest in the academic community in recent years (Pellegrino and Savona, 2017; Lars *et al.*, 2016; D'Este *et al.*, 2012; Fortuin and Omta, 2009). An obstacle to innovation is traditionally defined as something that prevents firms from embracing innovation initiatives and/or producing innovations. The literature clearly reports four types of barriers or obstacles to innovation (D'Este *et al.*, 2012; Pellegrino and Savona, 2017), namely: financial (Hall, 2002), knowledge-based (Galia and Legros, 2004), market-based and regulatory (D'Este *et al.*, 2012).

Financial obstacles are those related to lack of own funds, lack of external funding, and high costs of innovation. Knowledge obstacles include lack of qualified personnel, lack of information about pertinent technologies for innovation and difficulty in finding partners to cooperate in innovation initiatives. Market obstacles are usually related to situations in which markets are heavily controlled and dominated by incumbents, or to situations where there is

considerable uncertainty regarding demand for innovative products and services. Finally, regulatory obstacles are those bodies of law and regulations that could hinder or delay innovation processes, for example due to excessive red tape or prohibitions (OCDE, 2018).

A review of the literature on innovation obstacles allows us to identify two main dimensions between which works can be organized. The first dimension is related to the empirical method employed – quantitative or qualitative. And, the second dimension organizes studies according to the assumptions they make on what obstacles are – external barriers or internal constructions.

The works by Pellegrino and Savona (2017) and Zahler *et al.* (2018) can be thought of as representatives of the type of studies that are mostly based on quantitative methods. In these works, the authors resort to an array of different types of regression analyses to test the hypotheses they formulate and to establish relationships between innovation obstacles and outcomes. Both studies use standardized innovation surveys: the UK Community Innovation Survey in the first study and the Chilean National Innovation Survey in the second one. And, both works include firms from all industry sectors at the national level. Other relevant studies in this vein are Lanchenmaier and Wößmann (2006), Mohnen *et al.* (2008), Costa-Campi *et al.* (2014), Blanchard *et al.* (2013); all employing regression analysis to estimate obstacles to innovation in developed countries – Germany, the Netherlands, Spain and France, respectively.

The researches by Lars *et al.* (2016) and Fortuin and Omta (2009) provide examples of studies employing qualitative methods, more specifically, interviews with relevant actors. Both focus on unveiling the intricacies of innovation within the food sector in developed European countries. Along the same lines, Bar (2015) reports an interview-based case study of fish processing equipment companies. She investigates how green innovation can be integrated within the activities of the companies to secure sustainable fish processing in the future. Other relevant studies employing interviews and qualitative analysis are those of Liu and Wilkinson (2011) and Labafi (2017). The first one investigates the drivers and obstacles for adopting public-private partnerships in New Zealand and provides details on how these obstacles might be overcome by using innovative country-specific solutions. They use semi-structured interviews with senior industry players and roundtable discussions. The second one (Labafi, 2017) argues that the dissemination of knowledge and information can help organizations to be innovative and improve their competitive advantage. Using thematic analysis and interviews, this study shows that information does not freely flow through the employees of organizations. This is because many employees prefer to hide their organizational knowledge from their colleagues in order to maintain their own portfolios.

Regarding the second dimension we used to organize the literature on innovation obstacles, we observed two camps. The first one approaches obstacles as exogenous elements that work as actual impediments. The second one approaches obstacles as endogenous; more specifically, as elements constituted, to a substantive extent, by perception (D'Este *et al.*, 2012). The first approach is more often employed by economists that study innovation. Isolating exogenous effects is key for the identification of causal effects in this literature; moreover, it is a substantive concern in modern mainstream economics. Relevant works conceptualizing drivers and barriers as more external and/or objective are Hashi and Stojčić (2013), and Pellegrino and Savona (2017); which use the Community Innovation Survey (CIS) and focus on European countries.

However, the second approach is perhaps more realistic, because innovation surveys usually either directly ask for the perception of firms in relation to a given set of obstacles, or do very little to avoid firms answering based on their perception. In addition, the second approach is more interesting from a management point of view, because it attempts to study how firms make sense of, and evolve, their perceptions of obstacles as they encounter them; which has managerial implications. Relevant examples of studies taking the alternative

approach of considering barriers as, at least, partially construed by perception are De-Oliveira and Rodil-Marzábal (2019), and D'Este *et al.* (2012). In particular, the former study aims to analyze the influence of structural characteristics and organizational determinants on the perception of obstacles to innovation in small developing countries. The empirical analysis is based on panel data of 5,447 Ecuadorian firms from the National Survey of Innovation Activities. An interesting finding, they report, is that the perception of obstacles increases as the size of the company decreases, across all the different levels of innovation activity. This result is observed for all obstacles to innovation but is especially clear for the knowledge and economic barriers. Lastly, D'Este *et al.* (2012) argue that barriers can have two effects based on perception. More specifically, a barrier can be perceived as a "deterring effect" and a "revealed effect." For example, initially, when firms start pursuing innovation initiatives, a barrier can be perceived as a deterring obstacle. However, as firms engage in innovation their awareness and perception of the barrier can change, this is what they call the "revealed effect." The authors use data from the Fourth UK Community Innovation Survey (CIS4) to carry out their analyses.

Studying the perceptions of obstacles by firms holds great value for the literature on innovation, especially from an empirical standpoint, because it widens the array of possible explanations for the effects of barriers. For instance, a positive and significant relationship between a financial obstacle and innovation expenditures would usually make no sense from an economics-based perspective (Zahler *et al.*, 2018). Obstacles are supposed to preclude innovative activity; they are not supposed to be associated with more innovation. However, a perception-based explanation would argue that increases in reporting financial obstacles can be associated with more investment, because as firms spend more, they start realizing the financial implications of investing in innovation. This is related to the phenomenon of "revealed obstacles" described in D'Este *et al.* (2012), where the assessment of the importance of obstacles evolves as firms encounter them while carrying out innovation initiatives.

2.2 In food-related business and Chile

Regarding the food sector as a unit of analysis, there is not much literature studying barriers to innovation, be that in agriculture, food manufacturing, or other related industries. In the particular case of empirical studies, most of them are based on qualitative methods such as interviews. For example, Fortuin and Omta (2009) studied the food processing industry. This research was based on a study of nine multinational food processing firms with sizable operations in The Netherlands. Their work aimed to uncover the factors that constitute the main drivers and barriers to innovation in their location of interest. Among their key findings, they highlight the potential for open innovation ecosystems among suppliers and buyers; especially since the food processing industry faces strong international competition and ever-rising demands on the part of clients. However, they also find that such opportunities are still difficult to seize to their fullest.

In a similar fashion, Lars *et al.* (2016) investigated the role that retailers play in innovation in the food sector. Their research method was a qualitative analysis based on interviews. They interviewed food retailers and suppliers in Belgium, Denmark and the UK. One of their main findings was that retailers act both as guardians of the interests of final consumers and, at the same time, as barriers to innovation. This occurs because retailers are not interested in new technologies or innovation *per se*, but are interested in whether these innovations to final products bring clear benefits to consumers; which selects many innovative ideas before they reach any stage of maturity.

Finally, in the specific case of Chile, a country with high potential as global food supplier, there are no studies about innovation obstacles (to the best of our knowledge). There are works focusing on innovation, for example in the agricultural sector (Fuentes and Soto, 2015;

Geldes *et al.*, 2015), but none consider the concept of barriers to innovation. We believe there is an under-researched space here, where our study can contribute.

3. Methods

3.1 Data

To examine the relationships between obstacles, innovation spending and willingness to innovate, we used data from the Chilean National Innovation Survey (*Encuesta Nacional de Innovation*, ENI). The ENI is a nationally representative survey of Chilean firms, from all industries (Ministry of Science, 2020). It closely follows the guidelines stated in the Oslo Manual (OECD, 2018) and the Community Innovation Survey (Eurostat, 2020). The ENI is administered every two years to a sample of about 5,500–6,000 firms. It has been administered 11 times since 1996, and it is highly prestigious as a tool for policymaking.

We pooled data from the two latest versions of the survey, administered in 2017 and 2019. We selected only these two versions because older ones are not compatible with regards to our dependent variable of interest. More specifically, we wanted to study the relationship between obstacles to innovation and total innovation spending. But older versions did not include R&D as part of this type of expenditure. The 2017 and 2019 surveys are suitable for our study because they have exactly the same components of innovation expenditure; these include funds spent on R&D, facilities, training and others.

Finally, within the pooled 2017 and 2019 data, we selected only firms related to food production and elaboration. ENI follows the ISIC standard for industry classification (UN DESA, 2008), and we selected firms in the following industry sectors: agriculture and livestock farming (section A, division 01 in ISIC), fishing and aquaculture (section A, division 02 in ISIC) and food and beverage manufacturing (section C, divisions 10 and 11 in ISIC). These sectors have a clear connection with the food industry. They include firms that are in different positions within the supply chain of said industry, for example firms that supply inputs (agriculture, fishing, aquaculture and livestock farming) and firms that manufacture finished food products. Our final sample size is 1,727 firms. Panel A in Table 1 displays the number and percentage of firms in each industry category.

3.2 Innovation spending and willingness to innovate

To measure innovation spending, our dependent variable, we used the total expenditure on innovative activities that firms reported. Innovative activities are those carried out with the

	N	%
A. Industry		
Agriculture and livestock farming	745	43
Fishing and aquaculture	486	28
Food and beverage manufacturing	496	29
B. Firm Size		
Small	925	53
Medium	360	21
Large	442	26
C. Survey		
2017	817	47
2019	910	53

Note(s): Sample size = 1,727
Source(s): National Innovation Survey (Chile) 2017 and 2019

Table 1. Size, industry sector and survey version of the firms in the sample

goal of producing one or more innovations (being that a product, a service, or a process). More specifically, the survey asks firms to report all their innovation-related expenditures on: R&D (internal and outsourced), facilities, machinery, software, training, design, new product marketing and others. Our dependent variable is the sum of all that spending.

Additionally, in some of our analyses, we created a dichotomous variable which we call "Innovate." This variable takes a value of "1" if a firm invested funds in innovation (i.e. innovation spending > 0) and zero otherwise. This variable allows us to evaluate the willingness to innovate of a given firm. It is worth noting that ours is a conservative test, in the sense that it is not enough for a firm to declare that it carried out innovative activities to be classified as innovative in our sample, it needs to have spent actual money on those activities. Spending actual funds on innovative activities can be considered a strong indicator of whether firms are willing to pursue innovation or not.

3.3 Barriers to innovation – a factor analysis approach

The independent variables in which we are primarily interested are the barriers to innovation. In the ENI, firms were asked to answer the following question: "To what extent do you perceive the following obstacles to innovation have an influence in your firm?" There were a total of 12 obstacles that were classified as: cost factors, factors related to knowledge, market factors and other factors. Respondents could evaluate the influence of every obstacle as: none, low, medium or high. Appendix 1 shows each obstacle as presented in the questionnaire.

In order to uncover underlying factors among this set of obstacles, we carried out a factor analysis. This is substantively different from the approaches taken in most of the literature, where obstacles are grouped into factors solely on theoretical grounds (cf. D'Este *et al.*, 2012; Pellegrino and Savona, 2017). Instead, a factor analysis allows researchers to empirically determine whether a set of variables can be thought of as reflecting a small number of underlying factors (Treiman, 2009).

Table 2 shows the results of employing this procedure with a varimax rotation. Obstacles 1 to 3 have high loadings on factor 2 (acceptable loadings are of 0.5 or higher, Treiman, 2009); this we call the "cost" factor. Similarly, obstacles 4 to 7 load on factor 1; which we named the "knowledge" factor. Obstacles 8 and 9 load on factor 4 – the "market" factor. Finally, obstacles 10 and 11 load on factor 3 – the "no need" factor. Regulatory difficulty could also load on factor 3, however, its loading is not as high as the "no need" obstacles. For that reason, we opted for leaving it in its own category; which is also sensible from a theoretical perspective. Table 3 shows a reliability analysis employing the Cronbach's α criterion (Bollen, 1989). This

Table 2.
Factor loadings after varimax rotation

	Obstacle	Factor 1	Factor 2	Factor 3	Factor 4
1	Lack own funds	0.362	*0.752*	0.162	0.227
2	Lack of external funding	0.337	*0.779*	0.212	0.209
3	Innovation costs too high	0.358	*0.560*	0.217	0.357
4	Lack of qualified personnel	*0.698*	0.342	0.216	0.189
5	Lack of information about technology	*0.825*	0.287	0.205	0.212
6	Lack of information about markets	*0.779*	0.280	0.234	0.270
7	Difficulty to find partners for innovation	*0.612*	0.376	0.238	0.273
8	Market dominated by incumbents	0.397	0.349	0.248	*0.612*
9	Uncertain demand for innovative goods/services	0.372	0.317	0.256	*0.689*
10	No need due to previous innovations	0.166	0.168	*0.816*	0.124
11	No need due to lack of demand for innovation	0.237	0.140	*0.804*	0.168
12	Regulatory difficulty	0.274	0.260	0.593	0.254

Note(s): Selected high loadings for each factor are in italics

analysis indicates the degree of reliability that a set of items is measuring the same underlying factor (or latent variable). The Cronbach's α value of each factor was above 0.7, which is the minimum value commonly accepted to validate internal-consistency reliability (Fornell and Larcker, 1981; Treiman, 2009).

Subsequently, we standardized each of the 12 obstacles and calculated averages of them for each factor. For example, we constructed a variable called "cost" that corresponds to the average of the standardized versions of the obstacles: "lack of own funds", "lack of external funding" and "innovation costs too high." We applied the same procedure to build variables for the knowledge, market and no need factors. The regulatory factor is simply the standardized version of the original obstacle "regulatory difficulty."

3.4 Controls

In the analyses we present below, we include three important control variables. First, we controlled for industry sector. "Industry" is a categorical variable that includes the three sectors we described before, namely: Agriculture and livestock farming, Fishing and aquaculture and Food and beverage manufacturing. Second, we included a control for "Firm size." Size is defined according to the guidelines of the Chilean government (Ministry of Science, 2020). In this classification, a small firm is one with annual sales from (roughly) 100,000 USD to a 1 million USD, a medium-sized firm has sales from 1 million to 4 million USD, and a large firm has sales of more than 4 million USD. Finally, we also included a variable indicating the year of each survey; which can take two values: 2017 and 2019. Table 1 lists these controls, and their frequency in our sample.

3.5 Analysis

We carried out a linear regression analysis using Stata to analyze the relationship between the innovation obstacles we defined before – cost, knowledge, market, no need and regulatory – and innovation spending in the food production and manufacturing sector. To assess whether this same set of obstacles can be associated to the decision to innovate (spend money on

Dimension	Cronbach's α
Cost	0.930
Knowledge	0.876
Market	0.923
No Need	0.795

Note(s): Values above 0.7 are the usual standard for internal-consistency reliability

Table 3. Cronbach's α value for each dimension of obstacles to innovation

Variable	Mean	SD	Min	Max
ln Innovation spending	2.115	4.293	0.000	16.664
Innovate	0.208	0.406	0	1
Cost	0	0.898	−1.639	0.984
Knowledge	0	0.894	−1.541	1.203
Market	0	0.929	−1.570	1.091
No Need	0	0.931	−1.085	1.797
Regulatory	0	1.000	−1.178	1.525

Note(s): Sample size = 1,727

Table 4. Size, industry sector and survey version of the firms in the sample

innovation or not), we used logit and probit models. Table 4 presents the mean, standard deviation, minimum value and maximum value for all variables we use in the regression analysis (except for the controls already presented in Table 1). Additionally, Appendix 2 describes all variables used in the regression models in greater detail.

4. Results

Table 5 displays our regression analysis to assess the relationship of the independent variables of interest (the factors reflecting obstacles) with innovation spending. We ran all our models with robust standard errors. Model 1 is a regression that includes only the controls, and Model 2 is the full model also including the variables of interest. Both models show that the controls are important to explain differences in spending. Firstly, if we look at the firm size variable, we can see that both medium-sized and large firms invest significantly more in innovation compared to small firms (the omitted category). Also, large firms invest more than medium-sized companies. It is clear that as firms grow, they spend more funds on innovative activities. Secondly, the variable Survey 2019 is positive and significant. This means that firms reported investing more in innovation in the 2019 version of the survey than in the 2017 version (the omitted category). We will not try to hypothesize why that is so because we only have two time data points, so conjecturing about a time trend is unwarranted. Finally, the industry variable shows that firms in food and beverage manufacturing invest more in innovation than firms in agriculture and livestock farming, and more than firms in fishing and aquaculture (the omitted category). Thus, overall, manufacturing seems to be the most innovation-intensive sector in the food-related industries.

Regarding obstacles to innovation (the main focus of this study), Model 2 of Table 5 presents our main results. The cost obstacle was positively, and significantly, associated with innovation spending. This may seem counterintuitive at first, because we tend to think of costs as deterring firms from executing any kind of investment. We elaborate on this finding in the Discussion section below. Contrary to cost, the knowledge barrier was negatively, and significantly, associated with innovation spending. And, similarly, the "no need" barrier was negatively associated with investing in innovation. These two latter results are in line with

Table 5.
Linear regression models of several independent variables on Innovation Spending

Variables	(1)	(2)
Firm Size		
Medium	0.856*** (0.234)	0.842*** (0.232)
Large	3.368*** (0.300)	3.341*** (0.297)
Survey 2019	0.564*** (0.198)	0.513*** (0.197)
Industry		
Agriculture and livestock farming	0.501** (0.196)	0.478** (0.197)
Food and beverage manufacturing	1.284*** (0.270)	1.297*** (0.268)
Cost		0.560*** (0.180)
Knowledge		−0.389** (0.178)
Market		0.088 (0.174)
No need		−0.506*** (0.143)
Regulatory		0.137 (0.157)
Observations	1,727	1,727
R-squared	0.142	0.155

Note(s): ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$ (two-tailed tests). Robust standard errors in parentheses
Omitted category for survey is Survey 2017, for Firm Size is Small, and for Industry is Fishing and aquaculture

the idea that obstacles, by construction, should inherently deter innovation. However, we offer a perception-based interpretation in the Discussion section. Under this approach, a negative association may mean that firms assess a barrier as less important when they carry more innovation. A final result that we can observe in Table 5 is that the market and regulatory barriers were not significantly related to innovation spending.

Table 6 shows logistic and probit models for the dependent variable willingness to innovate. We present both models as a way to check for the robustness of the results to model specification. The regressions are to be interpreted as modeling the association between the five types of obstacles (and the controls) and the decision of spending funds on innovation. The control variables all behave very similarly to what we found in the previous models shown in Table 5. Large firms are more likely to make the decision to invest in innovation compared to medium-sized and small firms. Firms in food and beverage manufacturing are more likely to invest than firms in agriculture and farming, and in fishing and aquaculture. Finally, the logistic model suggests that firms in the more recent version of the survey (year 2019) were more likely to invest in innovation than firms in the 2017 version. However, we consider that this is not a strong result because it was not confirmed in the probit model.

Regarding our variables of interest, the cost barrier was positive and significant, meaning that firms that reported more problems with cost as an obstacle were more likely to make the decision to invest in innovation. On the other hand, the knowledge and "no need" obstacles were negative and significant in their association with the decision to invest in innovation. Again, we provide perception-based interpretations of these results in the Discussion section. This is especially insightful in the case of the cost barrier, where the results seem quite counterintuitive at first sight. Finally, the models in Table 5 also show that the market and regulatory obstacles were not significant. In general, the resulting models in Table 6 are well aligned with what was shown in the models of Table 5.

Variables	(1) Logistic	(2) Probit
Firm Size		
Medium	0.653*** (0.172)	0.365*** (0.096)
Large	1.511*** (0.153)	0.876*** (0.088)
Survey 2019	0.220* (0.131)	0.111 (0.074)
Industry		
Agriculture and livestock farming	0.451** (0.178)	0.237** (0.096)
Food and beverage manufacturing	0.762*** (0.182)	0.415*** (0.102)
Cost	0.418*** (0.117)	0.249*** (0.066)
Knowledge	−0.262** (0.121)	−0.152** (0.069)
Market	0.106 (0.117)	0.066 (0.065)
No Need	−0.308*** (0.095)	−0.168*** (0.054)
Regulatory	−0.003 (0.090)	−0.012 (0.052)
Observations	1,727	1,727
Log Likelihood	−788.559	−788.808
Wald χ^2	169.380	174.860
Degrees of freedom	10	10

Note(s): Omitted category for survey is Survey 2017, for Firm Size is Small, and for Industry is Fishing and aquaculture
Source(s): National Innovation Survey (Chile) 2017 and 2019.651
***$p < 0.01$, **$p < 0.05$, *$p < 0.1$ (two-tailed tests). Robust standard errors in parentheses

Table 6. Logistic and Probit regression models of several independent variables on Innovate

5. Discussion and conclusions

It is important to highlight again that in the survey we studied firms were asked to report their actual expenditures on innovation, in Chilean pesos; which can be considered as an objective quantitative measure. However, regarding obstacles, there is a difference in terms of metric type. More specifically, respondents were asked for their "perception" on the extent to which barriers were present in their firms (see Appendix 1). Therefore, we argue that the wording that is commonly used in surveys to identify obstacles is more amenable to the literature that treats obstacles as depending on perception. Firms answer questions about obstacles using their perception of them. And, we use these lenses to discuss our results below.

As mentioned in the Results section, the cost obstacle was positively and significantly associated with innovation spending (Table 5). This may seem counterintuitive, because the common conception is that higher costs should deter firms from attempting to innovate and, therefore, the association between cost and innovation should be of negative sign. For example, Zahler *et al.* (2018) assert that the influence of barriers should be of negative sign, and that barriers usually yield that result if the researcher is able to select only firms with a potential for being innovators. On the contrary, we do not need to discard firms from our sample in order to make sense of the results. Our findings are sensible if one takes into account that the cost variable is based on perception. What transpires is that as firms pursue more innovation, they spend more funds on it, and then come to realize about the associated costs. Consequently, they end up reporting more problems with costs, such as not finding enough funds inside or outside their organization to finance their innovation projects. Similarly, Table 6 shows that reporting cost as an obstacle was positively associated with deciding to invest funds in innovation. Following the same interpretation rationale used so far, this may mean that firms that make the decision to invest report more problems with costs, because by engaging in innovation they become aware of the associated costs.

We also found that contrary to cost, knowledge was negatively, and significantly, associated with innovation spending (Table 5). A sensible explanation is that having knowledge barriers deters spending. However, we again opt for a perception-based explanation. In this case, what is likely occurring is that as firms invest more in innovation, they realize knowledge is not such a strong problem. For example, they may start realizing that, if they look for it, they are likely to find partners and qualified personnel for innovation. This speaks well of the Chilean innovation ecosystem. It means that if a firm wants to invest in innovation, the initial knowledge learning curve can be overcome in time. This is in line with the findings of D'Este *et al.* (2012). They also found evidence of a positive association between the knowledge barrier and innovation, especially when firms increase their innovation efforts from one or two activities to three and up to seven. Another interesting finding was that innovation spending was negatively associated with the "no need" barriers. Again, a "revealed effects" (D'Este *et al.*, 2012) perception-based explanation would be that as firms begin to innovate, they also start realizing that there is actual need (and demand) for innovative products and services. In the case of this specific factor, it is difficult to find a benchmark in the previous literature, because "no need" obstacles have not been theorized before. Instead, we found this latent factor empirically, by performing the factor analysis described in the Methods section.

Finally, Table 6 shows that the knowledge obstacle was negative and significant, which may mean that as firms make the decision to innovate, they also realize that the knowledge barriers to innovation are not so important as a problem. And, the "no need" obstacle was also negative and significant in Table 6, which means that firms that decide to spend money on innovation are more likely to discard potential problems such as lack of necessity or lack of demand for innovation. Lastly, the market and regulatory obstacles were not significantly associated with the decision to innovate.

The results of this study also offer some interesting insights to firms and policy makers in the food sector, in particular in Chile, and in other countries that may consider themselves to have similarities with this Latin American nation. The first one is that among all the barriers to innovation, the only ones that seem to be significant are those related to cost, knowledge and lack of necessity ("no need"). Concerns regarding regulations and the market were less important (at least to the firms in this sample). Secondly, the knowledge and "no need" barriers were associated with firms that invest less or that do not invest. Thus, policy makers may find it useful to run campaigns to change those barrier perceptions among said firms. Finally, the fact that perceiving innovation as expensive is associated with firms that invest more in innovation may be a call to action for policy makers, because it may mean that their instruments for easing the costs of innovation for innovative firms are not working as planned.

Our research analyzes a sample that is representative of a country. In particular, our data was collected through the Chilean National Innovation Survey, which was run by officials from the Ministry of Economy and the National Institute of Statistics, employing internationally sanctioned standards about data collection on innovation (OECD, 2018; Ministry of Science, 2020). However, despite the fact the Chile may share similarities with other countries, we must note that our results are not representative of their realities. Therefore, a limitation of our study is that it is representative of only one country, and results cannot be directly extrapolated. In this vein, a potential avenue for future research is to carry out studies that follow our framing of the phenomenon of innovation obstacles in the food sector in other countries. At this point there are several countries all over the world that are employing OECD standards for innovation data collection (e.g. see data.uis.unesco.org). Thus, researchers could start running quantitative analyses with nationally representative data, with the ultimate goal of developing an integrated knowledge base that includes data and insights from many locations worldwide.

Another limitation of the study is due to its quantitative nature. We provide a perception-based interpretation of the results, but we do not provide information about how perceptions of obstacles are formed and evolve. This latter point could be addressed by carefully designing qualitative studies that focus (1) on understanding how firms come to conceive obstacles, (2) on identifying the factors that influence perception and (3) on uncovering the mechanisms by which perceptions change over time. A program of research along these lines may not only reward researchers with a rich understanding of innovation obstacles, but it would also be quite useful for policy makers. In particular, it would provide them with valuable insight on how to manage innovation obstacles, which, in turn, could help their countries to better respond to the many upcoming challenges in terms of food provisioning (FAO, 2018).

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Appendix 1

	High	Medium	Low	None
1. Cost Factors				
Lack own funds				
Lack of funding external to the company				
Innovation cost is too high				
2. Factors related to knowledge				
Lack of qualified personnel				
Lack of information about technology				
Lack of information about markets				
Difficulty to find partners to cooperate in innovation				
3. Market Factors				
Market dominated by incumbent firms				
Uncertainty about demand for innovative goods or services				
4. Other Factors				
No need due to previous innovations				
No need due to lack of demand for innovations				
Regulatory difficulty				

Table A1. "To what extent do you perceive that the following obstacles to innovation have an influence in your firm?" (mark with an X)

Appendix 2

Table B1.
Variable Descriptions

Variable	Description
Innovation Spending	Total expenditure on innovative activities. It corresponds to the sum of expenses on the following activities when they are intended to produce and/or introduce an innovation: (1) internal R&D, (2) outsourced R&D, (3) purchasing of machinery, equipment, software and buildings, (4) acquisition of knowledge (patents, copyright, licenses, know-how), (5) training (internal and external), (6) marketing, (7) design, (8) installation and start up and (9) others that the respondents may specify
Innovate	Binary variable based on the variable Innovation Spending. It takes the value "1" if Innovation Spending is greater than zero, and a value of "0" if Innovation Spending equals zero. This variable allows for evaluating the willingness to innovate of a given firm
Cost	To construct this variable, we first standardized the following variables: lack of own funds (obstacle 1), lack of external funding (obstacle 2) and innovation costs too high (obstacle 3). In other words, we rescaled them to have a mean of zero and standard deviation of 1. And then, we computed their average. More formally $\text{cost} = \frac{\text{STD(obstacle 1)} + \text{STD(obstacle 2)} + \text{STD(obstacle 3)}}{3}$
Knowledge	Average of the standardized versions of the variables: lack of qualified personnel (obstacle 4), lack of information about technology (obstacle 5), lack of information about markets (obstacle 6), difficulty to find partners for innovation (obstacle 7). Formally $\text{knowledge} = [\text{STD(obstacle 4)} + \text{STD(obstacle 5)} + \text{STD(obstacle 6)} + \text{STD(obstacle 7)}]/4$
Market	Average of the standardized versions of the variables: market dominated by incumbents (obstacle 8) and uncertain demand for innovative goods/services (obstacle 9). Formally $\text{cost} = \frac{\text{STD(obstacle 8)} + \text{STD(obstacle 9)}}{2}$
No Need	Average of the standardized versions of: no need due to previous innovations (obstacle 10) and no need due to lack of demand for innovation (obstacle 11). More formally $\text{cost} = \frac{\text{STD(obstacle 10)} + \text{STD(obstacle 11)}}{2}$
Regulatory	Standardized version of the variable regulatory difficulty (obstacle 12). More formally $\text{cost} = \text{STD(obstacle 12)}$
Firm Size	Categorical variable. It has three categories: (1) small firm – those with annual sales from USD 100 thousand to 1 million, (2) medium-sized firm – those with sales from USD 1 million to 4 million, and (3) large firm – those with sales of more than USD 4 million
Survey 2019	Binary variable indicating the version of the survey of a given observation: survey 2019 (if value = 1), and survey 2017 (if value = 0)
Industry	Categorical variable. It has three categories corresponding to the sectors we investigated in this research: (1) agriculture and livestock farming, (2) food and beverage manufacturing and (3) fishing and aquaculture

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