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Obstacles to Green Innovation: Evidence from Chilean Firms

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Obstacles to Green Innovation: Evidence from Chilean Firms

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In this paper, we explore the relevance of obstacles to green innovation in Chilean firms. We analyze differences in green innovation across firm size and industries and we explore which barriers have a greater impact on green innovators. We find that these innovators, in general, do face higher obstacles to innovation than similar but non-green firms. We conclude that, after controlling for other firm characteristics, the most relevant obstacles for green innovators are those associated with financial and knowledge aspects. This finding is relevant for the implementation of public policies aimed at enhancing green innovation in Chile.

1. Introduction

During the past few decades and first in developed countries and more recently in developing countries, there are increasing concerns regarding environmental effects of economic activity. The concept of sustainable growth is already part of the development strategy for many countries and several steps have been given to make economic growth compatible with environmental sustainability. According to Olawumi and Chan (2018) problems of sustainability have gained worldwide attention since the publication of the Brundtland Commission report (WCED, 1987).

In past decades, a growing number of consumers around the world have also been showing a preference for environmental-friendly companies and products. Wei et al. (2018) shows several examples of firms investing significant resources to develop and produce green products. They state that: "The 21st-century business landscape is challenged by greater demands for environmental corporate accountability."

The increasing implementation of environmental regulations and changes in consumer preferences raise questions about how firms respond to this increased focus on environmental issues and adapt to new challenges. For several industries, successfully being competitive on the international scale depends on how effective the firms are in minimizing the environmental impact of their activities. Innovations in processes and products are required to successfully compete in foreign markets. However, not much is empirically known about how this works in developing countries. In particular, the evidence is scarce about how different obstacles, such as financial or informational problems, affect innovation decisions and if these barriers are heterogeneous across firm characteristics.

The importance of obstacles to innovation is however a growing research area for the developed world. Surveys like the Community Innovation Survey (CIS) first administered in the EU have fueled this research leading to papers on the impact of perceived obstacles on innovation (Mohnen, et al. 2008; Savignac, 2008; D´ Este et al., 2012) and others analyzing differences in innovation barriers across firm characteristics (Santiago et al., 2017; De Fuentes et al., 2020; Arza and López, 2021; Ocampo-Wilches et al., 2020, Feldens et al., 2012).

Our paper utilizes self-reports on obstacles to assess the biggest drags on green innovators and how they differ compared to other innovators. By looking specifically at obstacles to green innovation in Chile, we contribute to this literature in two main dimensions. First, we present novel evidence for a developing country. Second, we investigate whether green innovators face similar or different obstacles than other innovators. This is relevant for implementing public policies aimed at supporting green innovation.

The paper is structured as follows. In the second section we review the relevant literature, while in the third we describe the data. In the fourth we analyze innovation obstacles. In the fifth we test which obstacles are more relevant for green innovators than for others. The sixth section concludes. Our findings reveal that green innovators face, in general, higher obstacles than non-green innovators. However, after controlling for industry and other firm characteristics, we find that financial constraints and lacking specific knowledge seem to be more relevant for green innovation in the case of Chile.

2. Literature Review

The literature on the relevance of innovation obstacles in the developed world has been increasing during recent years. The main objective of this research area has been

to estimate the impact of several perceived obstacles — financial and non-financial — on innovation outcomes (Mohnen, et al. 2008; Savignac, 2008; D´ Este et al., 2012). As it is expected that different firms are affected in different ways, there are also papers looking at the heterogeneous effects of obstacles across firms and industries (Costa Campi et al. 2014). Some of the evidence has also explored the existence of complementarities among innovation obstacles (Galia and Legros, 2004; Mohnen and Roller, 2005; Tello, 2021). In general, it has been found that, after dealing with the endogeneity of the obstacles and sample selection issues, self-reported obstacles are negatively associated with innovation outcomes and that some obstacles are more relevant for some types of firms.

There has been some research on the topic in developing countries. In particular, focusing on works for Latin America, De Moraes et al. (2020) analyzes the impact of financial and knowledge barriers on the propensity to collaborate with universities and research institutes for high-tech Brazilian SMEs. Cabral et al. (2020) has analyzed the relevance of innovation obstacles for Brazilian firms in natural resources-related industries. For Colombia, Ocampo-Wilchez et al. (2020) associates innovation outcomes with obstacles, finding that the most relevant seems to be demand uncertainty. In the case of Chile, Alvarez and Crespi (2015) have found a negative and large impact of financial constraints especially for small firms and for process innovation. Canales and Alvarez (2017) have provided similar evidence for the impact of barriers to knowledge. More recently, Zahler et al. (2022) jointly analyze the effects of several obstacles, showing that financial and market obstacles tend to be the most relevant. However, none of these studies analyze differences in innovation obstacles between green innovators and non-green innovators.

The literature about determinants of green innovation has been growing because governments, organizations, and enterprises have put more effort into green initiatives (Tariq et al., 2017). There are several papers looking at drivers/obstacles to green innovation (Cuerva et al. 2014; Bar, 2015; Marin et al., 2015; Amore and Bennedsen, 2016; Fernandez et al. 2021) and the impact of green innovation on firm performance (Kunapatarawong and Martínez-Ros, 2016; Stucki, 2019; Demirel and Danisman, 2019). The evidence about drivers and impact of green innovation has been surveyed by Tariq et al. (2017). Their conclusion is that determinants of green innovation are diverse, but they can be categorized in six main categories: (i) market factors; (ii) stakeholder pressure; (iii) technological factors; (iv) collaboration and networking; (v) organizational level factors; and (vi) social, cultural, and ethical factors. In addition, the authors conclude that: "a coherent picture of what fits drivers and consequences of green product and process innovation all together in a clear and meaningful way is still lacking."

In this research arena, there are some articles similar to our paper regarding the comparison of barriers according to firm characteristics. Santiago et al. (2017), using data for Mexico, addresses differences in the importance of innovation obstacles by firm characteristics such as sectoral affiliation, technological behavior, and their response to perceived obstacles. De Fuentes et al. (2020) compares innovation barriers for successful and non-successful innovators in Brazil and Turkey. Arza and López (2021), for Argentina, studies differences across firms' size and finds that SMEs are more affected by obstacles, particularly by cost obstacles. Another recent paper by Pekovic and Bouziri (2021) looks at differences between adopters and non-adopters of environmental management practices in France, finding that adoption of these

practices reduces cost and knowledge obstacles to innovation but has no significant effect on market obstacles. However, regarding our research, we are not aware of papers in Chile or other Latin American countries estimating the differences in drivers/obstacles for green and non-green innovators.

3. Data

We use the National Survey of Innovation (NSI). The NSI is carried out by the National Institute of Statistics and is administered every three years since 1995. We use the 2017 data. The questionnaire follows the guidelines of the latest version of the Oslo Manual (2018) developed by the OECD. There have been some modifications over time in the number and types of questions, but the main structure of the survey is similar over time. There are eight major sections: (i) types of innovations that the firm has carried out in the last two/three years, (ii) expenditure in innovation activities, (iii) sources of innovation and cooperation ideas, (iv) human resources available for innovation, (v) public financing, (vi) obstacles to innovation, (vii) intellectual property rights, and (viii) perspectives concerning future innovations.

The main unit in the data is the formal enterprise, which are sampled with stratification[1] from all companies in the National Directory of Companies in 2017, and that participate in any of the activities fin the International Standard Industrial Classification of all Economic Activities, United Nations Revision 4 (ISIC Rev. 4), in its national adaptation (ISIC4.CL 2012). These formal enterprises must also carry out their activities within geographical limits of the country and to have annual sales above $100,000 USD during the 2017 accounting year.

[1] The variables used for the stratification are economic activity, firm size, geographical location, and sales level.

There are several alternative ways of measuring innovation using this survey. One way is using inputs such as R&D investment or outputs such as patents and process or product innovations. In this paper, we use a dummy variable that takes the value 1 when the firm reports introducing any innovation during the last three years. This variable includes product, process, organizational, and marketing innovation. The exact questions used are in Appendix A.

This survey, like most following the European CIS that are administered in Latin America, does not directly ask about environmental-motivated innovations directly. Thus, we infer them using firms' responses about the importance of several aspects for introducing innovations. Using these responses, we define green innovators as those firms who state their decisions were motivated by reducing the environmental impact when innovating products and processes.

In Table 1, we present the incidence of innovation and green innovation across industries. As expected, there are large industry differences in the propensity to innovate. Green innovation has a lower incidence than innovation in general, but industries with a high propensity to innovate also have a higher incidence of green innovators. As shown in Figure 1, the correlation between both variables is positive and large.

In Table 2 we show information for propensity to innovate by firm size. Two facts are evident. First, as generally found in the related empirical literature, large firms are more innovative. This also holds for green innovation. Second, the ratio between green innovators and other innovators is similar within firm size. Then, we can infer that, controlling by size, propensity to innovate is similar for both groups of firms.

4. Innovation Obstacles

In this section, we explore differences regarding innovation obstacles for green innovators compared to other innovators. We analyze whether there are differences by obstacle type. We follow some recent literature looking at self-reported information about these obstacles and their impact on innovation outcomes.

In the survey the importance of different obstacles is ranked from 1 (no obstacle) to 4 (severe). The obstacles are grouped in four categories; financial, knowledge, market, and others (mostly associated with regulations). The relevance of the obstacles is explored using the following survey question: to what extent do you perceive the following obstacles or disincentives to innovation in your company?

The specific obstacles for each group are the following:

- Financial: lack of funds, lack of external financing, and high cost of innovation.
- Knowledge: Lack of qualified workers, lack of information about technology, lack of information about markets, and difficulties finding partners.
- Market: Market dominated by established firms and uncertainty about demand for innovations.
- Others: it is not necessary because of previous innovations, lack of innovation demand, and regulatory complexity.

Like previous papers looking at the impact of obstacles on innovation, we follow Savignac, (2008) and restrict the sample to "potential innovators," i.e., we exclude companies reporting that they do not innovate and that they do not face any obstacles. It has been shown in this literature that this selection reduces the bias associated with

the existence of firms that do not innovate and do not face obstacles. In fact, it has been found that only taking into account potential innovators, the relationship between innovation and obstacles is negative as it would be expected (Savignac, 2008).

In Figure 2, we show the average relevance of the four obstacle types. The average severity of obstacles is between 2 and 3, i.e. between low and medium. According to these numbers, the average firm in Chile does not face severe barriers to innovation. This is something surprising considering that a low and decreasing proportion of firms are innovating and R&D investment is stagnant below 0.4% of GDP.[2]

Looking at differences between green and non-green innovators, we find that there are differences in innovation obstacles between both groups, which can be seen in Table 3. In general, all obstacles are perceived as slightly more important for green innovators. We also analyze whether the relevance of innovation obstacles may be different for large and small firms. In fact, the literature shows that large firms have better access to financial markets and invest more in new technologies. The evidence shown in Figure 3 suggests that green innovators perceiving higher obstacles is higher for medium and large firms. In the case of small firms, with the exception of financial obstacles, green innovators face lower obstacles then general innovators.

[2] See results from the R&D Expenditure Survey in Chile. https://minciencia.gob.cl/legacy-files/20200409_resultados_encuesta_id.pdf

5. Econometric Results

To look at if the differences in obstacles are significant, we estimate the following model:

$$Y_i = \alpha + \beta GI_i + \delta X_i + \varepsilon_i$$

Where Y is an indicator of the relevance of the obstacle, GI is dummy for green innovators, and X is set of control variables (a dummy for exporters, a dummy for foreign firms, a proxy for productivity captured by the log of sales per worker, and the percentage of college workers on total employment). For all estimations, we include size and industry dummy variables.

In Table 5, 6, 7, and 8 we test whether there are differences for each individual obstacle by the four types. As the variables are discrete and follow a ranking from not important to severe, we run an ordered Probit for each one. In the case that green innovators were more affected that other innovators, the parameter β should be positive and significant.

The main finding of these regressions is that green innovators, in general, do face higher obstacles to innovation than other firms. The only exceptions are scarcity of qualified workers (Table 6), being in a market dominated by few firms (Table 7), and a lack of demand for innovation (Table 8), where the differences between innovators are not significant. From these regressions, we can conclude that, after controlling for other firm characteristics, there are relevant obstacles, mostly associated with financial and knowledge issues, affecting green innovation in Chilean firms.

In the case of control variables, we cannot infer causal relationships, but the correlations suggest that domestic firms and low-productivity firms are associated with higher obstacles to general innovation. In particular, exporters are more affected by lack of external financing, but not by knowledge obstacles. In the case of foreign firms and productivity, our estimations suggest a negative correlation with most of the obstacles considered.

6. Conclusions

Firms in developing countries are facing increasing challenges caused by new regulations based on environmental considerations and from new demands from external clients. One key response to these challenges is green innovation, but this can be limited by barriers or other obstacles. In fact, the evidence shows that firms in most developing countries are underperforming when it comes to green innovation. Also, there is little information about innovations based on environmental concerns.

This paper addresses both the incidence of green innovation and the main obstacles faced by Chileans firms. We find that while the incidence of green innovation is lower compared to overall innovations, but these are positively correlated with each other across industries. Second, similarly to most of the previous literature, we find that larger firms are more likely to innovate for environmental reasons than smaller firms. Third, green innovators generally face higher obstacles than other innovators. This is especially in terms of financial constraints, technological knowledge, marketing information, and uncertainty about demand.

This evidence has relevant policy implications regarding the creation of specific programs aimed to alleviate the barriers faced by green innovators. Most of the current

public instruments do not distinguish among types of innovation and are designed in a spirit of a "one size fits all" strategy. As we find, green innovators face higher obstacles in terms of financial constraints, thus may require more grant funding then other innovators or perhaps special programs aimed at improving their access to financial markets. Our findings also indicate that green innovators perceive higher barriers in gathering information about markets and technology. As information is a public good, this reveals that more work needs to be done in order to provide the type of knowledge required by green innovators. Our results also indicate that difficulties for finding innovation partners are more relevant for green innovators, which also suggests that information problems are a key issue in this context. Changes in governmental interventions is grounded not only in our findings regarding higher obstacles for environmental-related innovations, but also for the positive externalities associated with knowledge creation.

Table 1: Propensity to Innovate and Green Innovation by Sector

Sector	N	Propensity to Innovate (%)	Propensity to GI (%)	Green Innovators/Innovators (%)
Agriculture, forestry and fishing	656	9.5	6.8	65.5
Manufacturing	1048	24.7	14.2	65.7
Electricity, gas, steam and air conditioning supply	120	23.3	15.0	64.3
Water supply; sewerage, waste management and remediation activities	24	41.7	29.2	70.0
Construction	577	17.0	13.0	59.3
Wholesale and retail trade; repair of motor vehicles and motorcycles	683	14.3	6.0	40.2
Transportation and Storage	336	12.6	6.7	58.2
Accommodation and food service activities	277	16.9	11.3	53.2
Information and communication	340	34.3	12.6	44.1
Financial and insurance activities	176	6.6	2.7	40.0
Real estate activities	289	10.6	4.8	37.1
Professional, scientific and technical activities	279	18.4	10.4	53.6
Administrative and support service activities	275	20.2	8.4	38.5
Education	245	26.6	11.2	38.8
Human health and social work activities	244	13.4	10.3	53.8
Arts, entertainment and recreation	120	24.9	7.9	42.9
Other service activities	62	9.6	8.7	43.8

Source: Own elaboration with data from NSI 2017.

Table 2: Propensity to Innovate and Green Innovate by Firm Size

Firm Size	Observations	Propensity to Innovate (%)	Propensity to GI (%)	Green Innovators/Innovators (%)
Large	2406	29.4	13.0	53.6
Medium	1369	23.4	11.1	53.1
Small	2101	12.9	7.3	55.1

Source: Own elaboration with data from NSI 2017.

Table 3: Obstacles Averages for Innovators and Green Innovators

Type of Obstacle	Obstacle	Innovators	Green Innovators
Financial	Lack of Funds	3.30	3.40
	Lack External Finance	3.14	3.23
	High Cost of Innovation	3.32	3.48
Knowledge	Lack of Qualified Workers	3.03	3.24
	Scarce Tech Info	2.92	3.19
	Scarce Market Info	2.96	3.12
	Difficulties finding Partners	3.07	3.27
Market	Dominated Market	3.13	3.37
	Uncertainty about Demand	3.14	3.31
Other	Previous Innovations	2.61	2.90
	Lack of Innovation Demand	2.72	2.96
	Regulatory Complexity	2.65	2.91

Source: Own elaboration with data from NSI 2017.

Table 4: Characterization of Innovators and Green Innovators

Variable	Innovators	Green Innovators
Exports (%)	11.2	12.8
FDI (%)	4.2	3.1
Qualified (%)	22.4	20.9
Sales/Workers (ln)	11.4	11.0
Small (%)	70.9	74.9
Medium (%)	18.2	16.0
Large (%)	10.9	9.1

Source: Own elaboration with data from NSI 2017.

Table 5: Ordered Probit Estimates and Marginal Effects for Financial Obstacles

Variable	Lack of Funds		Lack External Finance		High Cost of Innovation	
	Coefficient	ME	Coefficient	ME	Coefficient	ME
GI	0.25***	0.08***	0.29***	0.09***	0.27***	0.10***
	(0.078)	(0.027)	(0.077)	(0.024)	(0.078)	(0.028)
Export	0.13	0.05	0.20**	0.06**	0.11	0.04
	(0.103)	(0.036)	(0.102)	(0.032)	(0.104)	(0.038)
FDI	-0.18	-0.06	-0.22*	-0.07*	-0.09	-0.03
	(0.122)	(0.043)	(0.122)	(0.038)	(0.124)	(0.045)
% Qualified	0.28*	0.10*	0.20	0.06	0.004	0.002
	(0.160)	(0.056)	(0.159)	(0.050)	(0.161)	(0.059)
Sales/Workers	-0.11***	-0.04***	-0.12***	-0.04***	-0.10***	-0.04***
	(0.033)	(0.011)	(0.033)	(0.010)	(0.033)	(0.012)
Size	Yes		Yes		Yes	
Sector	Yes		Yes		Yes	
Observations	*1017*		*1017*		*1017*	

Source: Own elaboration with data from National Innovation Survey . 2017

ME stands for the marginal effect of a change in an independent variable over the probability of the obstacle being perceived as High Pr(y=4). * p<0.1, **p<0.05, ***p<0.01.

Table 6: Ordered Probit Estimates and Marginal Effects for Knowledge Obstacles.

Variable	Lack of Qualified Workers		Scarce Tech Info		Scarce Market Info		Difficulties finding Partners	
	Coefficient	ME	Coefficient	ME	Coefficient	ME	Coefficient	ME
GI	0.07	0.02	0.24***	0.06***	0.20***	0.04***	0.23***	0.07***
	(0.076)	(0.022)	(0.076)	(0.018)	(0.076)	(0.017)	(0.077)	(0.024)
Export	-0.05	-0.01	-0.07	-0.02	0.09	0.02	0.04	0.01
	(0.101)	(0.030)	(0.101)	(0.023)	(0.100)	(0.022)	(0.101)	(0.032)
FDI	-0.16	-0.05	-0.21*	-0.05*	-0.25**	-0.06**	-0.22*	-0.07*
	(0.121)	(0.036)	(0.121)	(0.028)	(0.123)	(0.027)	(0.122)	(0.038)
% Qualified	0.04	0.01	0.08	0.02	0.20	0.04	0.07	0.02
	(0.158)	(0.046)	(0.156)	(0.036)	(0.157)	(0.035)	(0.156)	(0.049)
Sales/Worker	-0.10***	-0.03***	-0.04	-0.01	-0.12***	-0.03***	-0.05	-0.01
s	(0.033)	(0.010)	(0.033)	(0.008)	(0.033)	(0.007)	(0.033)	(0.010)
Size	Yes		Yes		Yes		Yes	
Sector	Yes		Yes		Yes		Yes	
Obs	*1017*		*1017*		*1017*		*1017*	

Source: Own elaboration with data from National Innovation Survey 2017.

ME stands for the marginal effect of a change in an independent variable over the probability of the obstacle being perceived as High Pr(y=4). * p<0.1, **p<0.05, ***p<0.01.

Table 7: Ordered Probit Estimates and Marginal Effects for Market Obstacles.

Variable	Dominated Market		Uncertainty about Demand	
	Coefficient	ME	Coefficient	ME
GI	0.11	0.03	0.16**	0.05**
	(0.077)	(0.023)	(0.077)	(0.024)
Export	0.15	0.04	0.11	0.04
	(0.102)	(0.030)	(0.101)	(0.032)
FDI	-0.10	-0.03	-0.26**	-0.08**
	(0.122)	(0.037)	(0.157)	(0.038)
% Qualified	0.12	0.04	0.02	0.006
	(0.157)	(0.047)	(0.157)	(0.049)
Sales/Workers	-0.09***	-0.03***	-0.04	-0.01
	(0.033)	(0.010)	(0.032)	(0.010)
Size	Yes		Yes	
Sector	Yes		Yes	
Observations	*1017*		*1017*	

Source: Own elaboration with data from National Innovation Survey 2017.

ME stands for the marginal effect of a change in an independent variable over the probability of the obstacle being perceived as High Pr(y=4). * p<0.1, **p<0.05, ***p<0.01.

Table 8: Ordered Probit Estimates and Marginal Effects for Other Obstacles.

Variable	Lack of Innovation Demand		Regulatory Complexity	
	Coefficient	ME	Coefficient	ME
GI	0.05	0.01	0.23***	0.05***
	(0.077)	(0.011)	(0.077)	(0.017)
Export	0.03	0.005	0.28**	0.06**
	(0.103)	(0.015)	(0.103)	(0.022)
FDI	0.14	0.02	-0.11	-0.02
	(0.123)	(0.018)	(0.123)	(0.026)
% Qualified	0.24	0.03	0.160	0.03
	(0.159)	(0.023)	(0.158)	(0.034)
Sales/Workers	-0.09***	-0.013***	-0.06*	-0.01*
	(0.034)	(0.005)	(0.033)	(0.007)
Size	Yes		Yes	
Sector	Yes		Yes	
Observations	*1017*		*1017*	

Source: Own elaboration with data from National Innovation Survey 2017.

ME stands for the marginal effect of a change in an independent variable over the probability of the obstacle being perceived as High Pr(y=4). * p<0.1, **p<0.05, ***p<0.01.

Figure 1

Green and non-green Innovators across Industries

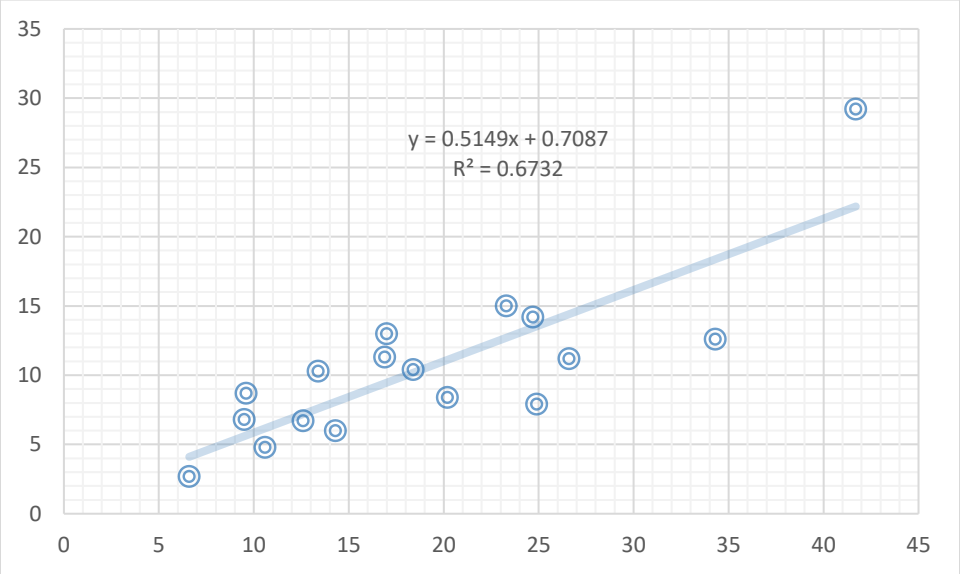


Figure 2

Perception of Innovation Obstacles

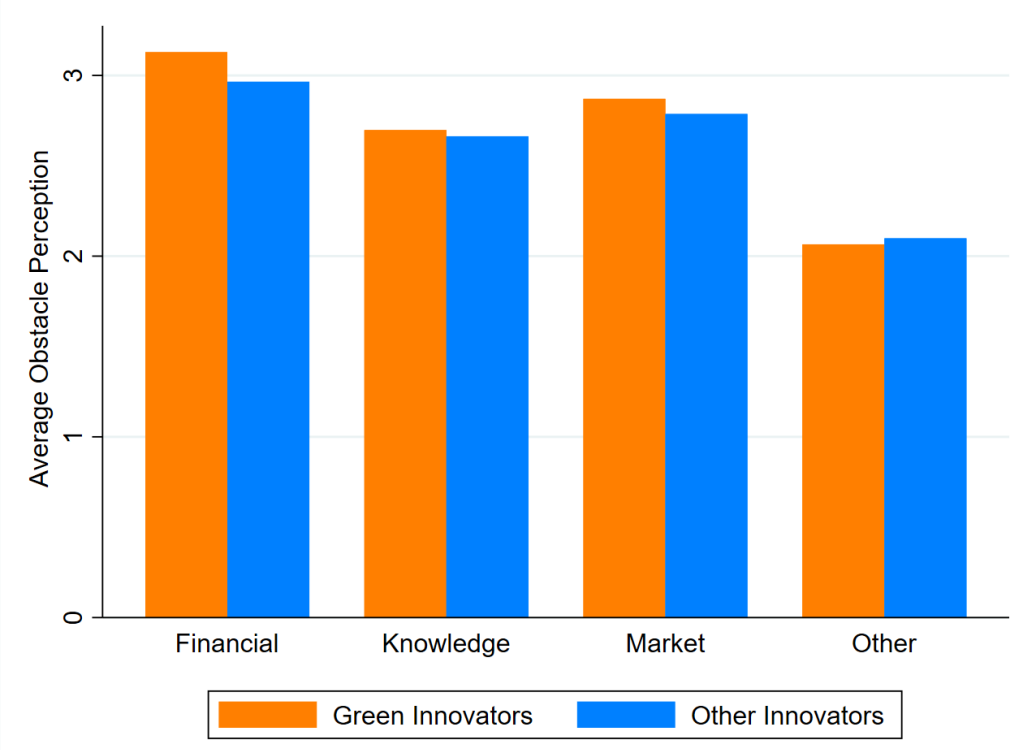
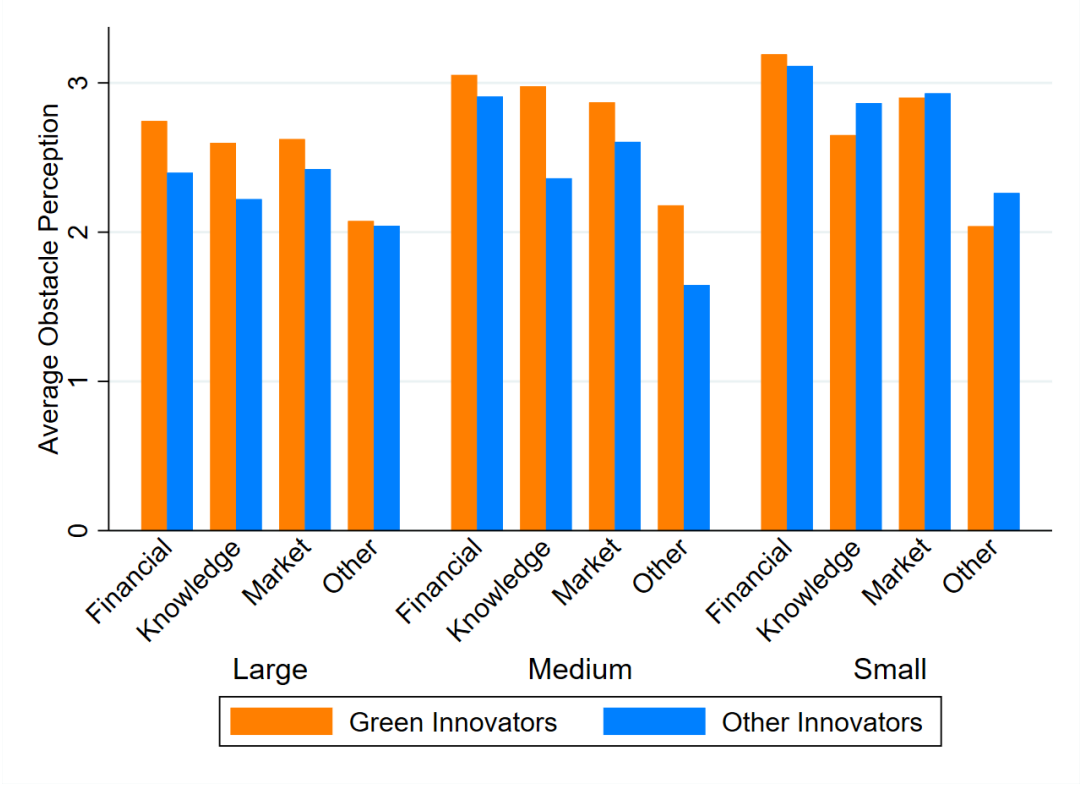


Figure 3

Perception of Innovation Obstacles by Firm Size



APPENDIX A: INNOVATION QUESTIONS

The survey contains several questions about innovation, with four main categories: product, process, organizational, and marketing. These are:

Product: During 2015/2016, did your firm introduce a new or significantly improved; (i) product or (ii) service?

Process: During 2015/2016, did your firm introduce a new or significantly improved: (i) production — of either goods or services — or manufacturing method; (ii) logistics, delivery or distribution method for your supplies, goods or services; or (iii) support activity for your processes such as a maintenance system or changes in purchasing, accounting, or IT operations?

Organizational: During 2015/2016, did your firm introduce: (i) new business practices for process organization, (ii) new organizational, or decision-making processes or related changes in responsibility, or (iii) new methods of managing external relations with other companies or public institutions?

Marketing: During 2015/2016, did your firm introduce; (i) significant changes in the design, packing, or packaging of products; (ii) new marketing means or techniques; (iii) new methods for product distribution; or (iv) new methods of pricing your goods and/or services?

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