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SYNERGIES ACROSS INNOVATIONS OBSTACLES AND THEROLE OF GOVERNMENT AID: EVIDENCE FROM CHILE

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Resumen

Esta investigación evalúa el impacto de barreras a la innovación en empresas chilenas, desde el punto de vista de sus complementariedades. Nuestro análisis empírico (2013-2018) revela la existencia de dos grandes grupos de obstáculos a la innovación altamente complementarios entre sí: un grupo que combina a las restricciones financieras, con impedimentos de cooperación científica, barreras de conocimiento y de demanda, y otro grupo que congrega a las restricciones de carácter regulatorio- institucional junto con factores de resistencia interna a innovar. Se observa que la presencia de cualquier grupo de obstáculos reduce la probabilidad de realizar actividad científica a nivel de empresa, además de reducir el impacto positivo de otros determinantes de la innovación (como la intensidad de I+D, la relevancia del tamaño de empresa y el uso de instrumentos de propiedad intelectual). Asimismo, se percibe que aquellas empresas que reciben apoyo público para la innovación responden de manera diferente al resto. Ante la presencia de estos obstáculos, empresas con subsidio gubernamental deciden, además, estrechar su interacción científica con otras entidades privadas a expensas de reducir sus vínculos de cooperación con instituciones públicas. Nuestros resultados brindan, por lo tanto, un amplio terreno para la formulación de políticas públicas, ya que subrayan la necesidad de abordar conjuntamente los impedimentos a la innovación (a partir de sus complementariedades), indican la importancia de fortalecer acuerdos cooperativos en materia de innovación entre empresas y entidades públicas de investigación, además de señalar a las restricciones regulatorias como una limitante importante a la actividad científica en Chile.

Palabras clave: *Barreras la innovación, Chile, Encuestas de Innovación.*

Abstract

This research explores the effect of synergies across innovation obstacles on the inventive activity of Chilean manufacturers. Empirical analysis over the 2013-2018 period highlights the prevalence of two types of synergies: one comprising financial, network, knowledge and demand constraints and, another pairing regulatory obstacles to internal resistance to innovate. The presence of either set of obstacle synergy reduces the likelihood to innovate and weakens other innovation determinants such as R&D intensity, firm size, and the use of instruments for intellectual property protection. Firms accessing public support for innovation are found to respond differently from the rest. They tend to react to such constraints by tightening their scientific interaction with other private entities at the expense of links with public research institutions. Our results provide ample ground for policy making as they underscore avenues to jointly tackle innovation impediments while pointing out differences among various types of cooperative arrangements and flag the presence of innovation deterrents stemming from rigid policy settings.

Keywords: *Innovation barriers, Chile, Innovation surveys*

Introduction

This paper explores the mechanism by which financial and non-financial barriers to innovate can influence both firms' innovation determinants as well as their probability to pursue strategies for technological innovation (process and product innovation). Addressing the influence exerted by obstacle synergies over these processes, tackling endogeneity concerns that are derived from the link between impediments to innovate and scientific activity, in addition to studying the role played by government aid in mitigating such constraints herein encompass the three major contributions of this work.

Chile is regarded as a relevant case study given its outstanding performance as one of Latin America's inventive economy. According to ECLAC (2022), this country has not only consistently reported one of the highest R&D investment in the region (as a proportion of GDP) but has also stood out as the economy with the greatest scientific productivity in relation to their peers. A pooled sample of Chilean firms reporting information on their corresponding inventive activity from 2013 to 2018 comprises our main source of micro-level data for this empirical assessment.

Our general results are summarized as follows. In accordance with the outcome generated by a logistic principal component analysis, obstacles to innovate in Chile can be clustered around two groups: one batch highlighting interdependences across financial, knowledge, network and demand barriers and, a second one stressing complementarities between regulatory obstacles and factors linked to internal resistance to innovate. Multivariate probit regressions and additional correspondence analysis further corroborate these latter groupings.

The impact of these two groups of obstacles over propensity to pursue technological innovation is later examined in the context of a probit estimation. Acknowledging issues of reverse causality, our instrumental variable approach includes (as an exogenous predictor) a firm-level indicator for the intensity of impediments to innovate. Within this regression, each obstacle synergy is observed to negatively influence likelihood to innovate. Other innovation determinants also included in the regression (such as size and the use of intellectual property rights) seem to weaken their relevance for firms' inventive activity in the presence of either interrelation. Firm-level factors like R&D intensity and cooperative agreements with other private entities, on the other hand, are

found to become inessential when the interdependence between financial, network, knowledge and demand barriers prevails.

Further insights are unfolded once we split our sample to separately consider firms with and without access to government aid for innovation. Despite the presence of synergies across obstacles, government funding and tax credits for R&D are empirically highlighted as pertinent policy tools nurturing private scientific interactions. Firms accessing these types of public support (SMEs with a lower-than-the-average R&D investment) and that face either group of impediments are able to heavily rely on cooperative projects with other private entities as a critical factor shaping its propensity for technological innovation. Nonetheless, additional room for policy intervention is here deemed as strongly necessary since, by the same token, cooperative agreements with public entities are found as an element negatively shaping probability to innovate regardless of obstacles synergies and access to government support.

This work is structured as follows. Section 2 presents our main objectives. Section 3 outlines our methods. This includes our conceptual framework (3.1) on the elements that define interactions across obstacles to innovate, a subsection describing our micro-level data for Chile (3.2), as well as our empirical approach to identify groups of impediments (3.3). Section 4 presents our main econometric results on the impact of obstacle synergies over likelihood to innovate (4.1), briefly discusses policy instruments for innovation in Chile and shows additional econometric results for the case firms accessing such type of public support (4.2). Section 5 concludes this research.

General Objectives.

a) To develop a conceptual framework (based on relevant literature) that highlights the mechanism whereby innovation barriers (and their complementarities) influence innovation outcome as well as firm-level determinants of scientific activity.
b) To identify (and quantify) different complementarities across individual categories of barriers to innovate (both financial and non-financial) through well-known data reduction empirical strategies.

c) To execute a probit estimation regression that assess likelihood to innovate and that considers the impact stemming from innovation determinants as well as the joint effect from synergies across financial and non-financial barriers.
d) To assess the role of government funding for innovation in alleviating the negative effect derived from the presence of synergies across barriers.

1. METHODS

1.1 *Conceptual framework*

Firm's inventive outcome can be negatively affected by the presence of financial and non-financial constraints. Prohibitive costs and budgetary limitations on firms' cash flow account for the set of financial impediments, while knowledge, demand, market an even regulatory related restrictions comprise the non-financial ones.

Given the recent large-scale availability of innovation surveys, the impact of these impediments has been empirically analyzed in relation to various indicators of inventive activity. These comprehend the use of variables signaling the pursuit of technological innovation (product and process innovation strategies), the quest for the non-technological one (organizational and marketing), indicators of inventive performance (the percentage ratio of new products and services being sold at the market with respect to total revenue), measures for firms' willingness to engage on scientific effort (R&D investment) and even indicators for the extent through which such expenditures takes place inside the organization (the ratio of R&D to sales).

Blanchard et al. (2012) argue that the negative repercussions over innovation activity induced by either kind of obstacles can be particularly observed if the group of non-inventive firms is excluded from the corresponding sample being assessed. Concurring with these considerations, Pellegrino and Savona (2017) further expanded such quantitative appraisal. They created a subsample of potential innovators which not only focused on firms aiming to innovate but that also filtered out for those units that struggled to engage on inventive efforts. By following this approach, these authors were then able to stress on the relevance of non-financial constraints. Market related barriers (such as concentrated market structure and lack of potential consumer demand) were identified as being as detrimental for innovation as the respective negative effect generated by financial constraints.

Two recent empirical studies make a case for obstacles to innovate in Chile. On the one hand, Ortiz and Fernandez (2022) explored the individual impact of impediments over the execution of different innovation strategies for a sample of firms comprising the agricultural, mining, manufacturing and services sector from 2006 to 2017. According to their results, financial restrictions stand as the single barrier with the highest negative influence over process innovation, while market and demand impediments play a more active role in discouraging product as well as organizational strategies. Knowledge, market and demand obstacles prevail as elements negatively configuring marketing innovation.

On the other hand, also with regard to Chile, Zahler et al. (2022) further emphasized the predominance of financial and demand barriers as the most detrimental factors reducing likelihood to innovate. In line with their findings, other particular impediments negatively shaping technological and non- technological innovation (such as knowledge constraints) only seem to become significant once these financial and demand constraints are explicitly excluded from the econometric regression. Just like the previous study, these authors focused on every major sector of economic activity in the country (including primaries and mining) but restrict their analysis to the years between 2009 and 2016.

In our view, despite such pertinent results, three central elements also configuring innovation constraints seem to not have been comprehensively explored thus far. These include the interdependence across different types of obstacles and their corresponding joint impact over scientific activity, the potential endogeneity (reverse causality) governing the interaction between such impediments and inventive outcomes, as well as the expected role of government aid in alleviating the negative repercussion that stem by the presence of those constraints.

Given their specific features, innovation obstacles tend to reinforce and complement one and other. For instance, the lack of qualified personnel can be tightly linked to insufficient financial funds. Such scarcity of knowledge and expertise can even allow for a growing uncertainty with respect to the potential resulting demand for the firms' inventive outcome. Shedding light on these synergies across innovation barriers is of high relevance as it underscores the need to devise policy instruments that seek to jointly tackle their complementarities instead of approaching them individually.

While carrying out Principal Component Analysis (PCA) and additional econometric tests, Mohnen and Rosa (2002) determine a number of complementarities among the set of innovation impediments faced by French firms within the service sector. These include the presence of high interdependences across barriers pertaining to economic risks (issues of appropriability, feasibility and marketing), strong correlations between the shortage of qualified labor and the unavailability of special machinery and equipment, as well as important linkages between internal resistance to innovation and administrative procedures, just to name a few.

Galia and Legros (2004) pursued a similar empirical assessment to determine potential synergies across those obstacles that induce either the suspension or deferment of scientific projects. In consonance with their correspondence analysis, the postponement of inventive projects can originate due to complementarities between organizational rigidities and information shortages as well as by the interdependences combining economic risks and sources of finance, among others. Synergies pairing lack of skilled workers and financial risks coupled with complementarities pertaining to institutional inflexibility and limited customer responsiveness seem to make a case for the decision to abandon projects.

Previous research has already underscored the idea that obstacles of any sort are likely to be endogenous on their relationship with innovation. For instance, Savignon (2008) argued that financial obstacles can lower the probability to execute scientific projects in the same way as innovative activity might induce economic difficulties for the firm. The same could be implied for other innovation barriers such as scarcity of expertise or inability to cooperate. Limited innovation capabilities might not only seriously compromise firms' competences to effectively exchange intangible knowledge but also undermine their participation on inventive projects with other key players operating elsewhere. Bivariate probit models and instrumental variable regression encompass the econometric tools that have been primarily utilized to correct for the above-mentioned endogeneity of innovation constraints.

A final note regards to the role of government aid. Policy instruments like direct access to public resources along with the granting of tax credits for R&D can too be considered as additional elements influencing impediments to innovate. In our view, they can do it so by strengthening the relevance of innovation determinants (say R&D intensity) on top

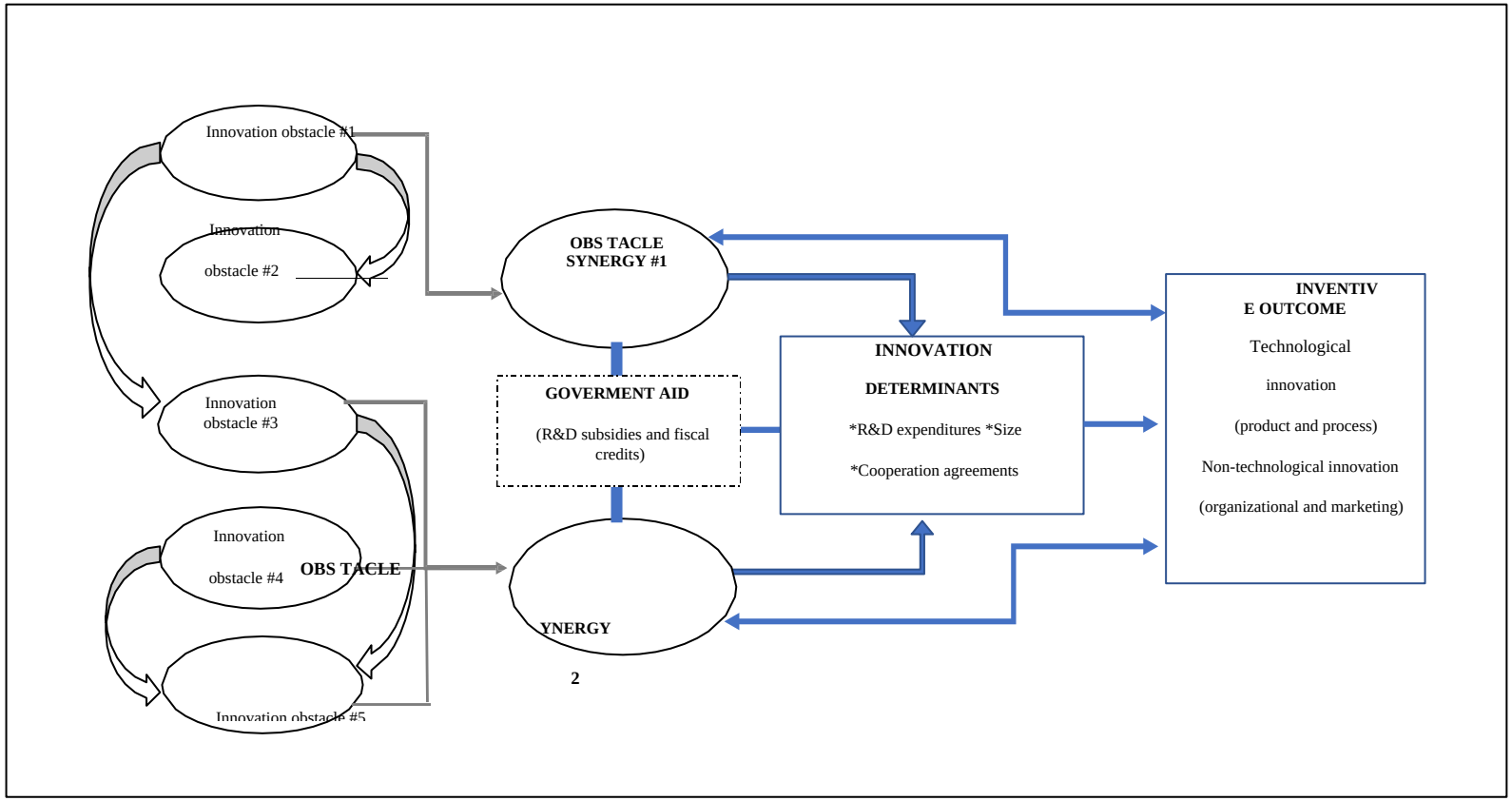
of alleviating (or even suppressing) the adverse consequences that are observed in the presence of these restrictions. Nevertheless, to the best of our knowledge, the extent through which those instruments of public support can actively participate over these processes has not yet been empirically explored. Having introduced these general discussions, we now proceed to outline the conceptual framework that will govern our quantitative appraisal as well as define our empirical expectations. Such scheme is herein briefly summarized in figure (1).

As a result of persisting synergies with one and other, individual financial and non-financial obstacles to innovate can also jointly burden firms' inventive activity. To evaluate the effect exerted by those synergies, groups comprising various individual barriers can be formed conditional on their attributes and the specific nature of their interdependence. Financial, knowledge and cooperation impediments might, for instance, be clustered around a single category since low cash flows tend to limit the acquisition of skilled labor thus eventually obstructing ability to cooperate with other enterprises. The same analogy results compatible for the rest of obstacles. The sole presence of such complementarities is herein foreseen to influence innovation activity by way of two channels; a direct impact over propensity to innovate and, an indirect one affecting other firm-level determinants of innovation (R&D intensity, size, instruments of intellectual property and, so forth). Following existing literature, we expect the direct impact to negative shape likelihood to innovate. With regard to the indirect one, we predict an ambiguous result. Depending upon the specific features of innovation determinants, the presence of obstacle synergies might either increase (or diminish) their importance over firms' probability to pursue scientific outcome.

Access to public support for R&D is herein anticipated to act as an element mitigating the effects triggered by innovation constraints. These could be observed either by a reduction (or even suppression) of the above mentioned direct and indirect effects.

Endogeneity issues are to be reckoned and remedied within this framework given evident concerns of reverse causality between innovation activity and their respective obstacles. An instrumental variable approach is then deemed as highly necessary to properly validate the ideas and conclusions posed by this work.

Figure (1): Conceptual framework on the impact of obstacle synergies on innovation determinants and inventive outcome



Source: Authors

1.2 Data

Chilean innovation surveys biannually divulged by the country's statistical office (Instituto Nacional de Estadísticas, INE) consitute our main source of micro-level information. Such datasets report a large number of innovation related variables including predominant type of innovation strategy being pursued (product, process, organizational and marketing), composition of R&D expenditures, availability of skilled workers, individual obstacles to innovate being faced by firms, policy instruments to support scientific activity, among others.

Our research will rely on a recent pooled sample of firms (generated by INE) which contains standardized micro data from the 9th, 10th and 11th waves of the country's innovation datasets and that range the period between 2013-2018. Aside from addressing a more recent and shorter time span, our research differs too from the recently advanced works on Chile in that we solely focus on the dynamics within the manufacturing sector.

In line with the general guidelines outlined in our conceptual framework, a subsample of inventive firms is hereby produced. Following Blanchard et al. (2012) and Pellegrino and Savona (2017) we filtered out the initial pooled of Chilean firms sample to solely consider those entities reporting innovation activities of any sort, that had ongoing or abandoned scientific projects and that have also faced at least one obstacle to innovate over time. Firms not meeting either of these criteria were then explicitly excluded from the analysis.

2. Complementarities across impediments to innovate.

As per the information provided within our innovation surveys, economic units in Chile face the follow set of constraints on their inventive activity;

- Financial obstacles (FINOBS) which are comprised by the lack of internal and external sources of funding as well as by prohibitive cost to innovate.

- Knowledge obstacles (KNOBS) which resemble shortage of highly skilled labor and insufficient firms' awareness with respect to available technologies and current market trends.

- Network obstacles (NETOBS) highlighting inability to cooperate on scientific projects with other entities.

• Demand obstacles (DEMOBS) that relate to the market predominance of well-established producers and the resulting uncertainty on the future potential demand of given inventive outcome.

• Regulatory obstacles (REGOBS) signaling bureaucratic burdens and excessive administrative procedures to formalize R&D projects.

• Other general obstacles (OTHER) comprehending the lack of interest to innovate due the prevalence of already well-functioning solutions and/or the absence of a specific market niche to position an invention.

As can be observed, correlation table (1) reveals a high level of complementarities across two groups of individual obstacles: one important association between financial, knowledge, network and demand barriers and, a second interdependence connecting regulatory constrains and other general impediments to innovate. In order to formally aggregate these latter correlations into general categories of obstacle synergies, our research executed a Logistic Principal Component Analysis (LPCA). This statistical technique is here implemented as it represents a unique data reduction method when binary information is only available. This is our particular case given the fact that obstacles to innovate in Chile are solely reported using a dummy variable format.

Table (1). Correlation between obstacles to innovate

	FINOBS	KNOBS	NETOBS	DEMOBS	REGOBS	OTHER
FINOBS	1					
KNOBS	**0.565**	1				
NETOBS	**0.476**	**0.542**	1			
DEMOBS	**0.544**	**0.509**	**0.454**	1		
REGOBS	0.313	0.323	0.394	0.374	1	
OTHER	0.208	0.244	0.243	0.303	**0.452**	1

Computed correlation used pearson-method with listwise-deletion.

The main results from our LPCA approach are shown in table (2). For the ease of simplicity, we only introduce the first two components generated by this analysis, their corresponding cumulative variance, along with the respective loadings reported by individual obstacles within each of these two dimensions. As anticipated, and in line with those loadings, we observe that financial, knowledge, network and demand can indeed be aggregated into a single category (here labeled as "OBS1"), while regulatory and other type of obstacles are also clustered around a second tier (here named "OBS2"). Also in line with these results, we note that components OBS1 and OBS2 are able to explain a large proportion of the variability across individual impediments to innovate given the fact that their joint percentage of cumulative variance is found to be of nearly 70%.

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Table (2). Logistic PCA

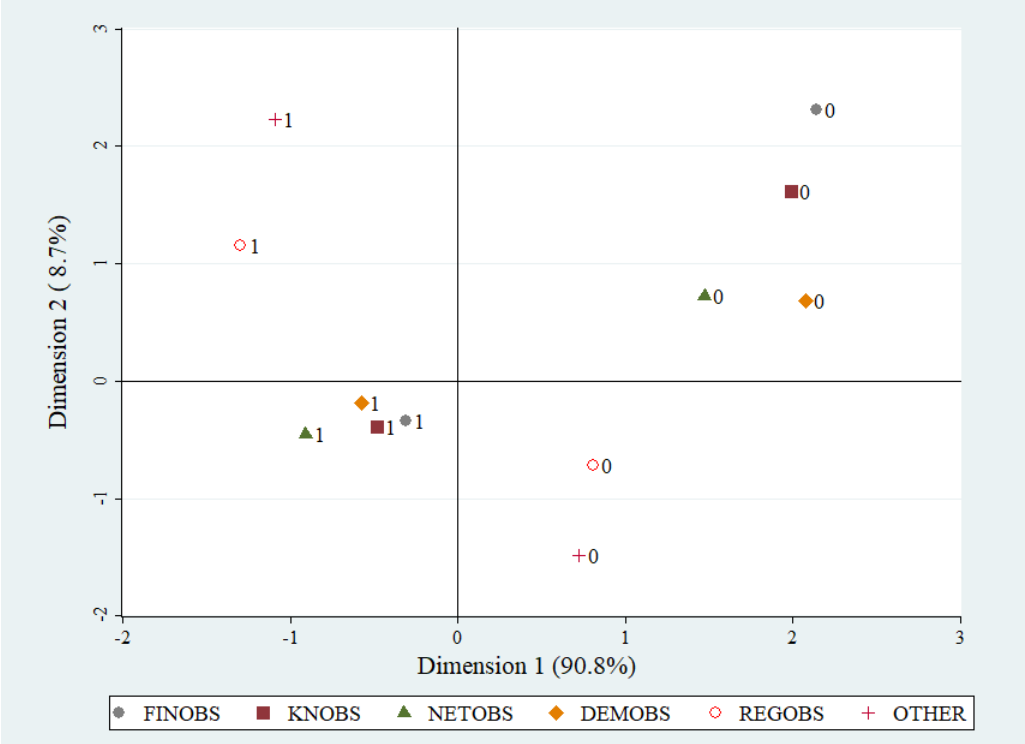
Obstacle	OBS1	OBS2
FINOBS	**0.197**	0.157
KNOBS	**0.204**	0.116
NETOBS	**0.189**	0.015
DEMOBS	**0.201**	0.074
REGOBS	0.111	**0.317**
OTHER	0.098	**0.321**
PDE	**0.51**	**0.69**

To more accurately validate the main results derived from our logistic PCA method, a few supplementary analyses are next provided. These will seek to further justify our

choice to merely utilize the first two LPCA components as well as better corroborate the grouping of individual obstacles there contained.

Standard PCA methodology typically exhorts scholars to only utilize those PCA dimensions whose eigen values are found to be higher than 1 (the Kaiser criterion). Nevertheless, since the LPCA approach does not report such information, our research decided to validate our choice for two dimensions through the execution of multiple correspondence analysis. This particular method follows the same rationale behind standard PCA and is too well suited to account for the presence of binary observations. The resulting associations across innovation barriers that stem from the correspondence analysis are introduced in figure (2) through a coordinate plot.

Figure (2). Multiple correspondence analysis: coordinate plot of binary responses to innovation impediments



From such a graph, we detect a clear pattern whereby different responses to innovation barriers tend to be clustered together. Positive and negative answers over financial, knowledge, demand and network constraints form a respective group of their own. This pattern is too observed when other and regulatory barriers are examined. Even more so, the cumulative variability explained by each dimension within this figure accounts for

nearly 100% of the total variance across impediments. Therefore, based on these additional results, we uphold our decision to solely rely on the first two general components generated by our logistic PCA approach (OBS1 and OBS2).

Our final appraisal to corroborate interdependences across innovation barriers relates to an additional correlation assessment through the implementation of Multivariate Probit Analysis (MVP). This econometric procedure entails examining the resulting correlation between generalized residuals that originates after individually regressing each impediment to innovate with respect to common explanatory variables. Following Galia and Legros (2004) and Mohnen and Rosa (2002), we conducted our MVP analysis based on the next set of independent regressors: size, type of ownership (domestic or foreign owned), general type of R&D expenditures (intra-mural and extra-mural), presence of cooperation agreements with other firms, and existence of training activities for workers.

Appendix A.1 outlines the operationalization of each variable employed on these regressions along with their respective descriptive basic statistics. Conversely, appendix A.2 shows the main MVP econometric results.

Table (3) introduces the resulting correlation across generalized residuals singly reported per innovation obstacle. As can be inferred, our initially presumed interdependence across two main groups of obstacles (one batch comprising financial, knowledge, network and demand barriers and a second group connection regulatory and other constraints) still prevails even when the effect of various explanatory variables over each individual barrier is accounted for.

Table (3). Disturbance covariance matrix derived from MV Probit regression: all inventive firms

	FINOBS	KNOBS	NETOBS	DEMOBS	REGOBS	OTHER
FINOBS	1					
KNOBS	0.379	1				
NETOBS	**0.466**	**0.486**	1			
DEMOBS	**0.484**	**0.428**	0.384	1		
REGOBS	0.351	0.210	0.379	0.401	1	
OTHER	0.196	0.144	0.316	0.281	**0.529**	1

Computed correlation used pearson-method with listwise-deletion.

Complementarities comprising components OBS1 and OBS2 thus constitute the two main type of obstacle synergies influencing innovation activity across Chilean manufacturers. The rationale behind the interactions contained in OBS1 stand as straightforward. Tight monetary resources largely explain the inability to acquire skilled labor (which also prevents firms to effectively exchange tangible and intangible knowledge with other entities) thus resulting on an increasing unawareness with regard to the pressing trends in consumer demand. On the other hand, the logic behind the interaction between regulatory impediments and obstacles pertaining to internal resistance to innovate deserves a more detailed explanation. Excessive and rigid bureaucratic procedures that seek to regulate and promote R&D activity might also dissuade firms' intention to pursue inventive projects within its own area of expertise.

For instance, limiting public support for R&D to a few priority sectors (explicitly excluding risky projects as well as those that provide alternative solutions to already existing industry-level problems) might induce firms to not intend innovation activities as they neither operate nor possess the necessary skills to engage on those publicly supported sectors. In this way, regulatory obstacles can further contribute to internal resistance to innovate as they intend to foster private R&D investment in areas outside the immediate competence and interest of given firms.

3. Results And Discussion

3.1 *Econometric análisis*

This section depicts our econometric strategy to describe the impact of innovation determinants and obstacles synergies over firms' likelihood to innovate. A dummy variable signaling either the presence of product or process innovation strategies (i.e., technological innovation) represents our dependent variable. As independent predictors, we include the following variables that typically configure firms' inventive activity: R&D intensity, informal methods of intellectual property (IMIP), size, cooperation agreements with other private firms (COF), as well as the existence of collaborative projects with other research institutions (CREO). Appendix A.3 shows descriptive statistics along with the respective operationalization of each of these regressors.

Logistic PCA scores for components OBS1 and OBS2 are too included within our probit regression. Such scores were generated in the last empirical section and, thus, embody the firm-level effect of existing synergies across financial, knowledge, network and

demand obstacles (OBS1) as well as that between regulatory constraints and other obstacles to innovate (OBS2). In order to gain additional insights over the effect exerted by such synergies, our research will conduct four different probit estimations: a pure regression model exclusively examining innovation determinants; a second and a third model now including the impact of synergies OBS1 and OBS2, respectively, and; a fourth probit estimation accounting for the simultaneous presence of these two.

In light of endogeneity concerns derived from the relationship between barriers to innovate and inventive activity, an instrumental variable approach will be followed for the case of the probit regression models 2 to 4. As an instrument, we will compute an indicator initially proposed by Zahler et al. (2022) which seeks to capture the exogeneity of innovation barriers. Given the fact that innovation constraints can vary depending on geographical, sectoral and time-related factors, these authors built an empirical measure for the average intensity of these barriers that explicitly incorporates such considerations. Our research, nonetheless, slightly adapted this indicator to only consider groups of obstacles according to their above-described complementarities. Appendix A.7 formally introduces the construction of this latter instrument along with our proposed alteration.

Table (4) presents our econometric results. Following previous argumentations, column (1) refers to our pure model, while columns (2) to (4) denote instrumental variable regressions[1]. Year and sectoral dummies are included on each respective specification. By observing column (1), it can be concluded that in the absence of innovation obstacles, nearly all of the independent regressors there considered positively increase likelihood to execute technological innovation. Cooperation agreements with other research institutions (CREO) represents the sole exception since it reports a negative but non-significant coefficient.

As per the ideas set by our conceptual framework, direct and indirect effects stemming from the inclusion of obstacles synergies are largely observed. Since either obstacle complementarity studied in columns (2) and (3) shows a statistically negative coefficient, we confirm the direct detrimental role that these two play in reducing likelihood to innovate. The expected unambiguous indirect effect over innovation determinants that is derived from the presence of OBS1 and OBS2 also prevails. For instance, according to column (3), existing complementarities between regulatory factors and internal resistance to innovate seem to reduce the relevancy of R&D intensity, IMIP, size, and

private cooperative agreements as elements positively shaping technological innovation. These latter synergies embodied in OBS2 appear likewise to heighten the negative impacted exerted by collaborative projects with research institutions.

Complementarities between financial, market, knowledge and network barriers (OBS1), on the other hand, are perceived to yield a more profound effect. Due the inclusion of these synergies in column (2), size and instruments of intellectual property remain as the sole statistically significant determinants of technological innovation when compared to initial pure model introduced in columna

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Table (4). Instrumental variable probit regression elements influencing likelihood of technological innovation.

DV: Technological innovation	(1)	(2)	(3)	(4)
R&D_intensity	0.074***	0.001	0.049**	0.001
	(0.02)	(0.01)	(0.01)	(0.01)
IMIP	0.411***	0.335***	0.326***	0.336***
	(0.12)	(0.09)	(0.09)	(0.09)
Size	0.109***	0.137***	0.071**	0.137***
	(0.03)	(0.02)	(0.02)	(0.02)
COF	0.668***	0.165	0.573***	0.156
	(0.13)	(0.09)	(0.10)	(0.09)
CREO	-0.256	-0.204	-0.404***	-0.182
	(0.15)	(0.10)	(0.11)	(0.11)
OBS1		-0.184***		-0.185***
		(0.00)		(0.01)
OBS2			-0.200***	0.018
			(0.01)	(0.01)
Constant	0.035	-0.831***	0.685***	-0.895***
	(0.16)	(0.14)	(0.14)	(0.15)
Pseudo R^2	0.063	--	--	--
Wald test (Chi^2)	--	201	113	219
Wald test (p-value)	--	0.000	0.000	0.000
Cragg-Donald(F-st)	--	75.464	192.076	40.913
Sectoral dummies	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES
Observations	1,531	1,531	1,531	1,531

[1] Tests for the exogeneity and strength of our preferred instruments are included at the bottom panel of table (4). For every specification, the Wald exogeneity test rejects the null of no endogeneity, while the Cragg-Donald F-test accepts the alternative that the instruments are not weak.

(1). The influence that synergy OBS1 exerts over these two, nonetheless, does not seem to be homogenous since the size variable is now perceived of higher relevance while the initial positive effect of intellectual property is reduced. Such situation seems to largely persist even when both groups of obstacles synergies (OBS1 and OBS2) are simultaneously accounted for (column 4). In addition, as too predicted by our conceptual, financial obstacles (here embodied in OBS1) can indeed come across as elements offsetting the respective impact induced by other less detrimental barriers. This is empirically confirmed by the fact that the corresponding coefficient for OBS2 is found as non- significant once synergies in OBS1 are also incorporated in regression output at column (4).

4. The role of public support for innovation

Direct financial provisions and tax credits comprise the main policy instruments to support private inventive projects in Chile. Monetary resources for innovation are granted through a wide array of government schemes conditional on performance and on the fulfillment of program specific pre- requisites. Some of the major public sponsors for this type of investment include Chile's Economic Development Agency (CORFO), the country's Innovation Authority (CONICYT), government programs targeting the development of the agro-industrial and fishery sectors (FIA and FID, respectively), as well as the support provided by centers for excellence research under the framework of the Millennium Scientific Initiative (ICM). On top of this, Chile's R&D law provides a 35% tax credit for firms pursuing R&D investment, which is therein computed considering such entities' total inventive expenditure over a given year. Economic units engaging on collaborative projects with other domestic or foreign owned firms are particularly eligible for these types of fiscal credits.

Since our innovation surveys contain information on each of the recently advanced lines of financing for innovation, we decided to split our initial sample of inventive enterprises in Chilean manufacturing to separately account for those with and without access to such government aid. Entities within our dataset that report receiving either type of R&D grant or tax credit are regarded as publicly supported firm, while the opposite will hold for enterprises reporting none of the above.

Information per type of public support considering size, R&D intensity and inventive strategy is herein introduced through appendix tables (A.4) to (A.6). As can be observed, public schemes advocating private R&D investment in Chile have mainly targeted small and medium sized firms that mostly followed a combination of product and process innovation strategies and, that generally scored a lower-than-the-average R&D intensity. In comparison, our sub-sample without public aid is primarily comprised of medium-sized and large firms mostly pursuing other general strategies (marketing and organization) with a relatively higher-than-the average R&D to sales ratio.

Table (5) shows our econometric results for the influence of government aid over obstacle synergies and innovation determinants. Panel (a) reports regression output for the case of firms accessing R&D grants and fiscal credits, while panel (b) shows the corresponding results for entities without such support. Within each respective panel,

columns (1) to (4) follow the same logic as initially described in table (4). For the case of publicly supported firms, in the absence of innovation obstacles, probability to innovate is exclusively affected by size (column a.1). Even though policy instruments for innovation were previously described to mainly target SMEs, firms of larger size appear to be the ones widely benefiting from such aid when no constraints to inventive activity are being considered. This latter effect, nonetheless, does not seem to prevail as we shift our analysis to the next immediate columns in panel (a).

Two innovation determinants show highly contrasting effects once obstacles synergies are included in these regressions. Firms accessing government aid seem to increase their interaction with other private entities at the expense of limiting their links with public research institutions. On the one hand, in line with columns (a.2) to (a.4), we observe that regardless of the occurrence of either obstacle synergy, publicly supported firms tend to primarily rely on private cooperative agreements as the predominant element influencing their propensity to perform technological innovation.

This latter outcome can be indubitably linked to the specific requirement set by the Chilean government whereby firms eligible for tax credits are explicitly asked to engage on collaborative projects with other private entities as a condition to access this type of support.

On the other hand, cooperative projects with public institutions are found to reduce probability to innovate across the same sub-sample of firms. When compared to the baseline regression (column a.1), the presence of obstacle synergies appear to accentuate the negative of effect of CREO since their respective coefficients (being shown at columns a.2 to a.4) tend to become more profound and statistically significant. Factors related the persistence of bounded innovation capabilities across public institutions (which prevents them from successfully commercializing scientific output) coupled with the presence of government incentives that seek to prioritize collaboration among private agents unequivocally explain these issues.

Table (5). Instrumental variable probit regression elements influencing likelihood of technological innovation.

	Panel (a): Firms with access to public support				**Panel (b): Firms without access to public support**			
DV: Technological innovation	(a.1)	(a.2)	(a.3)	(a.4)	(b.1)	(b.2)	(b.3)	(b.4)
R&D_intensity	0.079	-0.051	0.016	-0.068	0.079***	0.009	0.054**	0.009
	(0.05)	(0.05)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)	(0.02)
IMIP	0.501	0.217	0.399	0.268	0.440***	0.384***	0.314**	0.389***
	(0.30)	(0.20)	(0.20)	(0.20)	(0.13)	(0.10)	(0.11)	(0.10)
Size	0.263***	0.123	0.001	0.084	0.087**	0.140***	0.068**	0.140***
	(0.07)	(0.07)	(0.06)	(0.06)	(0.03)	(0.02)	(0.02)	(0.02)
COF	0.453	0.491*	0.720***	0.565**	0.742***	0.113	0.571***	0.110
	(0.29)	(0.23)	(0.20)	(0.21)	(0.16)	(0.10)	(0.12)	(0.10)
CREO	-0.142	-0.421*	-0.635***	-0.539**	-0.394*	-0.115	-0.517***	-0.088
	(0.29)	(0.21)	(0.19)	(0.20)	(0.19)	(0.14)	(0.15)	(0.14)
OBS1		-0.203***		-0.206***		-0.182***		-0.184***
		(0.01)		(0.01)		(0.01)		(0.01)
OBS2			-0.290***	-0.057			-0.189***	0.022
			(0.01)	(0.04)			(0.01)	(0.02)
Constant	-1.031*	-1.409***	0.938**	-1.098**	0.244	-0.753***	0.737***	-0.827***
	(0.41)	(0.32)	(0.33)	(0.39)	(0.18)	(0.16)	(0.16)	(0.17)
Pseudo R^2	0.204	--	--	--	0.058	--	--	--
Wald test (Chi^2)	--	40	72	133	--	172	86	183
Wald test (p-value)	--	0.000	0.000	0.000	--	0.000	0.000	0.000
Cragg-Donald(F-st)	--	15.508	20.338	10.614	--	64.835	162.139	34.506
Sectoral dummies	YES	YES	YES	YES	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES	YES	YES	YES	YES
Obs.	241	241	241	241	1,290	1,290	1,290	1,290

Following the same stream of ideas, we also observe that, despite particularly targeting firms with lower-than-the-average inventive expenditures, access to government aid does not seem to increase the relevancy of R&D intensity on propensity to innovate. Instruments of intellectual property are not deemed either as pivotal elements for technological innovations by these publicly supported entities.

Finally, for the case of enterprises not receiving government incentives for innovation (presented at panel b), we note no major 290escribe don290 with respect to 290esc initially 290escribe don table (4) which corresponds to the entire sample of Chilean manufacturing inventive firms. Complementarities across innovation obstacles tend to reduce propensity to innovate (direct negative effect) and, in most cases, they also weaken the statistical significance of innovation determinants (indirect ambiguous effect). Barrier synergies under component OBS2 are too offset by the interplay between financial, knowledge, market and network impediments to innovate.

5. Conclusions And Points For Discussion

This paper aimed to evaluate the mechanism through which innovation activity is negatively affected by the presence of impediments to conduct scientific activity across Chilean manufacturers. Previous research has extensively addressed this issue by exclusively focusing on the individual impact from given obstacles to innovate. Our empirical work deviates such from existing literature in that we consider the role played by obstacle complementarities in conditioning innovation determinants as well as likelihood to innovate. These analyses were herein performed through the lenses of a recent pooled sample of inventive enterprises which was compiled and produce by Chile' Statistical Office for period 2013-2018. Our general conclusions can be summarized as follows.

Financial, network, knowledge and market barriers (OBS1) reinforce one and other and, thus, they can jointly discourage innovation outcome. Inventive activity can also be daunted by virtue of the high interdependence between regulatory restrictions and factors pertaining to internal resistance to innovation (OBS2).

While the sole presence of these two synergies directly reduces propensity to pursue technological innovation (process and product innovation strategies), their indirect effect over innovation determinants appears as less straightforward. Firm-level factors such as size

and the use of instruments for intellectual property protection still positively influence innovation regardless of the presence of either obstacle synergy. R&D intensity and the existence of inventive projects with other private firms only seem to become essential when the complementarities under OBS2 are only considered. Cooperation activities with other research institution come across as an element severely discouraging likelihood to innovate also in the sole presence of this latter interdependence. Even in the simultaneous presence of OBS2, the direct and indirect effects exerted by constraints in OBS1 are found to largely prevail over innovation propensity and their determinants.

Splitting the sample of inventors between firms with and without access to government aid allowed us to unravel additional insights with respect to the indirect effect over innovation determinants that is generated from the occurrence of such complementarities. Firms eligible for R&D tax credits (or that receive some sort of public funding for innovation) tend to heavily rely on private cooperation agreements as the single critical element positively shaping its probability to conduct technological innovation regardless of the incidence of any synergy. Such interesting empirical conclusion can be explained by a specific policy measure devised by the Chilean government whereby firms accessing public support for innovation are required to engage on scientific projects with other privately owned economic units.

Nevertheless, as a potential side effect, access to government aid also seems to conversely discourage collaborative projects between inventive private firms and public institutions. These specific types of cooperative agreements are found to negatively condition private scientific activity in the presence of any type of obstacle synergies and regardless of the granting of public support.

Finally, with regard firms to without government aid for innovation, we noted that their response to synergies across impediments largely resemble the direct and indirect mechanism initially described for the case of all inventive Chilean firms.

Beyond recommendations to jointly tackle innovation obstacles in accordance with the potential complementarities here outlined, this empirical work also underscore the need to better adapt existing policy incentives to not only target private agents but also other relevant public entities operating within the country's national system of innovation. Government aid for innovation in Chile should not merely prioritize increasing collaboration across private entities but also aim for a closer interaction of these with public research institutions.

As it the case for the average developing economy, such institutions produce and absorb the vast majority of highly qualified labor and execute most of the R&D investment in the country. Including incentives for scientific collaboration between public and privately owned entities as part the general conditions to access government aid will surely reinforce scientific research across wider segments of the national innovation system and even assist on the country's efforts to boost private R&D investment.

6. References

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Appendix

Table A.1. Descriptive statistic and operationalization of the variables included on the Multivariate probit regression.

Variable	Name in regression	Mean	Std. Dev.	Coef. Var.	Max.	Min.	Operationalization
Financial obstacles	FINOBS	0.79	0.41	0.52	1.0	0.0	Binary variable for the presence of limited monetary resources, lack of external funding and occurrence of prohibitive costs.
Knowledge obstacles	KNOBS	0.73	0.44	0.61	1.0	0.0	Binary variable for the lack of qualified personnel as well as shortages of technical and market knowledge
Network obstacles	NETOBS	0.58	0.49	0.85	1.0	0.0	Binary variable for the occurrence for the lack of cooperation agreements
Demand obstacles	DEMOBS	0.72	0.45	0.63	1.0	0.0	Binary variable for the existence of market- related uncertainties such as target market being dominates by well-established producers
Regulatory obstacles	REGOBS	0.38	0.48	1.29	1.0	0.0	Binary variable for the presence of regulatory difficulties
Other type of obstacles	OTHER	0.43	0.50	1.15	1.0	0.0	Binary variable of the presence of lack of prospective demand for innovation outcome and the existence of well-functioning solutions
Size	Size	3.81	1.41	0.37	9.68	0.00	Total labor employed by the firms

Multinational firm	MNE	0.10	0.30	2.99	1.0	0.0	Binary variable for the presence of foreign owned investment inside the firm
R&D intra-mural	R&D intra-mural	0.69	0.46	0.67	1.0	0.0	Binary variable for presence of intra-mural R&D.
R&D extra-mural	R&D extra-mural	0.39	0.49	1.26	1.0	0.0	Binary variable for presence of extra-mural R&D.
Cooperation activities	Cooperation	0.19	0.39	2.04	1.0	0.0	Binary variable existence of cooperation activities with other firms or institutions
Training activities	Training	0.20	0.40	2.02	1.0	0.0	Binary variable for the execution of training activities for the improvements of skills within the organizations

Table A.2. Multivariate Probit regression: all inventive firms						
	(1) FINOBS	(2) KNOBS	(3) NETOBS	(4) DEMOBS	(5) REGOBS	(6) OTHER
Size	-0.096*	-0.147***	-0.053	-0.047	-0.029	-0.101**
	(0.04)	(0.04)	(0.03)	(0.04)	(0.03)	(0.04)
MNE	-0.083	-0.416**	-0.550***	-0.393**	-0.046	0.155
	(0.14)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
R&D intra-mural	-0.152	-0.017	0.288*	0.180	0.174	-0.304*
	(0.14)	(0.13)	(0.12)	(0.13)	(0.12)	(0.12)
R&D extra-mural	-0.044	-0.142	0.055	-0.209	-0.174	-0.197
	(0.14)	(0.13)	(0.12)	(0.13)	(0.12)	(0.13)
Cooperation	0.213	0.283*	-0.461***	-0.120	-0.038	0.300*
	(0.14)	(0.13)	(0.12)	(0.13)	(0.11)	(0.12)
Training	0.009	-0.072	0.061	0.277*	0.059	0.080
	(0.12)	(0.11)	(0.10)	(0.11)	(0.10)	(0.10)
Constant	1.545***	1.533***	0.560***	0.949***	-0.131	0.181
	(0.19)	(0.18)	(0.15)	(0.16)	(0.15)	(0.16)
Observations	720	720	720	720	720	720

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table (A.3). Descriptive statistics and variables included on the instrumental variable regression.

Variable	Name in regression	Mean	Std. Dev.	Coef. Var.	Variance	Max.	Min.	Operationalization
Technological innovation	tech inno	0.15	0.35	2.41	0.13	1.00	0.00	Binary variable accounting for the presence of product or process innovation strategies
R&D intensity	R&D_inten	8.42	2.21	0.26	4.88	13.76	-0.62	The ratio of R&D expenditures to firms' sales
Informal methods of	IMIP	0.08	0.26	3.50	0.07	1.00	0.00	Binary variables for the use of instruments of

intellectual property								intellectual property
Size	Size	4.14	1.45	0.35	2.10	8.98	0.00	Total labor employed by the firms
Cooperation with other firms	COF	0.10	0.29	3.08	0.09	1.00	0.00	Binary variable for the occurrence of cooperative projects with other private firms.
Cooperation with other research institutions	CREO	0.06	0.23	4.08	0.05	1.00	0.00	Binary variable for the presence of cooperation agreements with research institutions
Obstacles Synergies #1	OBS1	-3.54	5.05	-1.43	25.54	9.52	-9.42	LPCA scores embodying interdependences across financial, network, demand and knowledge barriers
Obstacles Synergies #2	OBS2	2.87	4.04	1.41	16.36	8.00	-7.84	LPCA scores embodying interdependences regulatory and other barriers related to internal resistance to innovation

Table A.4. Number of inventive firms per type of funding and size (2013-2018).

Type of firm	Small	Medium	Large	Total
No funding	648	1,852	1,100	3,600
Funding	185	154	71	410
Total	833	2,006	1,171	4,010

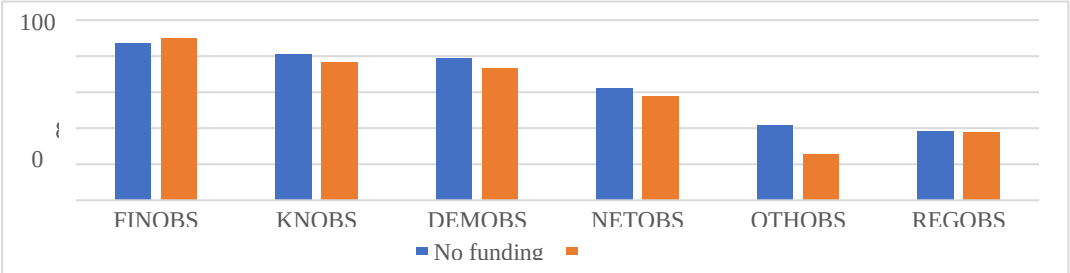
Table A.5. R&D intensity per type of firm (2013-2018).

Type of firm	2013	2014	2015	2016	2017	2018	All years
No funding	8.24	8.32	8.47	8.61	8.75	8.85	8.53
Funding	8.28	8.37	7.64	7.05	8.05	8.05	7.96
All firms	8.25	8.33	8.32	8.36	8.66	8.74	8.44

Table A.6 Number of inventive firms per type of funding and per innovation strategy being pursued (2013-2018)

Type of firm	Product inno.	Process inno.	Product and process	Other inno. strategy	Total
No funding	284	754	546	2,016	3,600
Funding	86	98	116	110	410
All firms	370	852	662	2,126	4,010

Figure A.1 Percentage of firms facing different obstacles to innovate.



A.7 Intensity of innovation obstacles.

Following Zahler et al. (2023), our instrument to account for the endogeneity of innovation obstacles can be built as follows:

$$\underset{s,r,t}{k} \qquad \frac{intensity^{kj}_{i,s,r,t}}{n(\Xi_{s,r,t})}]^{n(k)} \equiv \sum [\sum$$

$$j \epsilon k \quad i \epsilon \Xi_{s,r}$$

Where $intensity^{k}$ indicates the severity through which constraint ***j*** affects innovation activity at firm ***i*** operating at sector ***s*** which is located within region ***r*** at time ***t***. **j** constitutes each of the binary responses on innovation obstacles as reported by our sample of inventive firms, while **k** represents our proposed grouping of obstacles synergies (obs1 and obs2). The intensity levels described by this instrument range from 0 (being the lowest) to 1 (being the highest). $n(\Xi_{s,r,t})$ comprises the group of inventive firms established in sector s in region ***r*** at time ***t*** (the cardinality of $\Xi_{s,r,t}$) and $n(k)$ introduces the number of questions categorized at group of obstacles synergies.

$_{s,r,t}$