Public support of innovative activity in small and large firms in Mexico

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Abstract:

The National Science and Technology Council (CONACYT) was established in 1970 by the Mexican government. CONACYT was formed to promote the scientific development and technological modernization of Mexico through developing high-level human resources, encouraging research projects, and disseminating scientific/technological information. In 2009, CONACYT launched the Innovation Stimulus Program (PEI) to foster enterprises' innovation activities and to encourage collaboration on innovation activities among firms and between firms and public research institutes and higher education institutions. Based on an analysis of project data from the PEI program over the years 2009 through 2014, we found that large firms are more innovative than small firms. And, firms that are more innovative are those that had prior funded research, collaborated with universities in the funded research project, added new employees during the research project, and faced larger markets for their innovations.

Plain English Summary Only a few studies have systematically compared publicly supported innovative behavior between groups of large and small firms within developing countries, and absent from this list is an analysis of Mexico. In this paper, we study research projects funded through Mexico's Innovation Stimulus Program, and we find that large firms are more innovative than small firms. We also find that firms with previously funded research, that collaborated with universities in the funded research project, that added new employees during the research project, and that faced larger markets for their innovations are more innovative. Thus, the findings in this paper might provide an initial indication about those firms that will have a greater innovation-related response to the public funding to support their research.

Keywords: public program evaluation | innovation | R&D | Mexico

Article:

Introduction

The National Science and Technology Council (Consejo Nacional de Ciencia y Tecnología, CONACYT) was established in 1970 by the Mexican government under the leadership of President Luis Echeverría-Álvarez. CONACYT was a public and decentralized program to promote the scientific development and technological modernization of Mexico through developing high-level human resources, encouraging research projects, and disseminating scientific/technological information (Crespi & Dutrénit, 2013). CONACYT was responsible for the elaboration of science and technology policies in Mexico.

Since the promulgation of the Law to Enhance and Promote Science and Technology in 1999, CONACYT established a variety of programs to support innovative activity in both the public and private sectors (Dutrénit et al., 2010). According to CONACYT (2018, p. 19), the nature of these programs was to solve at least three market failures related to (a) costs of asymmetric/incomplete information about R&D investment; (b) internationalization and learning costs associated with the pioneer inventor that generate positive externalities to followers; and (c) the lack of coordination costs between private and public partnerships, affecting the R&D processes.

From 2001 to 2009, CONACYT implemented a number of programs to enhance science and technology in the country, including a research and development (R&D) tax incentive program that was active from 2001 to 2009 (OECD, 2013).[1] However, this fiscal stimulus program was re-designed to direct transfer modality given the low business productivity derived from their low private investments and critical problems across the education-science-technology-innovation chain. After the expiration of the tax incentive program, CONACYT launched the Innovation Stimulus Program (Programa de Estímulos a la Innovación, PEI)[2] in 2009 to foster innovative activity. More specifically (OECD, 2013, p. 44):

> [The PEI program] has two main objectives: to foster enterprises' innovation activities through the provision of subsidies for R&D and innovation-related costs, including those pertaining to the training and incorporation of highly skilled human resources; to encourage collaboration among firms and between firms and public research institutes (PRIs) and HEIs [higher education institutions] on research and innovation activities.

As inferred from the quoted passage above, the PEI program represented a public-private R&D partnership. Over the period 2009 to 2014, to which the data below relate, about 9.5 billion pesos (over $460 million in nominal US dollars) were invested through the PEI program. Of this amount, about 47.5% came from the funded firms, about 33.4% came from the government, and about 19.2% came from PRIs and HEIs (hereafter, simply from the universities). From 2009 to 2018, the PEI supported nearly 6000 applied research projects or/and prototype projects (Villarreal et al., 2019).

Although the PEI program ended in 2018 (Roces, 2018) because of the CONACYT's budget re-assignation and discontinuity of its trust fund during the 2018–2024 Mexican Administration, it remains as a reference for future administrations in Mexico and in other emerging countries,

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[1] See Cunningham and Link (2021) for a comparative analysis of tax incentive programs among OECD and other countries.

[2] Similar innovation stimulus programs have been implemented in Canada (NCR-IRAP innovation assistance program for over 70 years), Ireland (Enterprise Ireland's Innovation Vouchers Program established in 2007), Saudi Arabia (Cooperative technological innovation centers since 2012), and the United Kingdom (Innovation Vouchers for SMEs established in 2007) (CONACYT, 2018).

such as the APEC countries, to emulate innovation (APEC, 2018; CONACYT, 2018; Crespi & Dutrénit, 2013; Pastor et al., 2017).[3]

Three years after the end of the PEI program and discontinuity of the Mexican Entrepreneurship Institute (INADEM), the Mexican Innovation and Entrepreneurship Eco-systems still is attracting many Latin-American inventors and entrepreneurs (CORFO, 2020, p. 1):

> Mexico is an important destination for innovation, technology and entrepreneurship in Latin America. If investors or entrepreneurs reach the Mexican market, they will have resources, a qualified workforce, the ability to reach other countries, and most importantly, they will be able to generate intelligence and added value for their solutions.

Surprisingly, however, innovation activity associated with PEI has yet to be documented in any systematic manner. As well, one is hard-pressed to identify in the academic literature empirical studies of innovative activity in Mexico.[4] Given the lack of comparable information, only a few studies have evaluated the impact of technology development funds (TFD) or support programs in Latin-American economies through the benchmarking of national innovation surveys (e.g., Bogliacino et al., 2012; Crespi & Zuniga, 2012; Hall & Maffioli, 2008; ITAM, 2008). This paper begins to fill that void through an empirical analysis of available project data from the PEI program over the years 2009 through 2014.[5]

The remainder of this paper is outlined as follows. In Section 1, we describe data on 683 PEI program funded firms that pertain to the innovation success of each project. In Section 3, we offer an econometric model to describe covariates with the innovation success of each project, and we present our empirical findings. The paper concludes in Section 4 with a discussion of our findings in light of the purposes of the PEI program to foster innovation and to encourage collaboration among firms and between firms and PRIs and HEIs.

Description of the data

Administrators at CONACYT graciously provided information on the 683 firms that received research support from the PEI program during the period 2009 through 2014. The information provided relates to all firms that received two or more awards during that period.[6] In this paper, we rely on detailed firm information and funding information for each firm's most recent award, and we rely on information about whether the funded firm received any previous awards from the PEI program.

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[3] Different Mexican incentives and social programs have been replicated in multiples countries in Latin-America, Asia and Africa (The World Bank, 2014).
[4] In fact, our review of the academic literature identified only two published empirical studies on innovative activity in South American countries. One study focused on Brazil (Frank et al., 2016) and the other study focused on Argentina (Chudnovsky et al., 2006).
[5] This paper is not an assessment of the PEI program because we do not have comparative information about the innovative activity of firms that applied for PEI support but did not receive it. We urge the reader to view this paper as a source of descriptive information about the PEI program in an effort to provide information for other such programs in Mexico or in other countries.
[6] The reason for CONACYT delimiting the dataset was to provide information on the most recent award as well as information on previous awards received for comparative purposes.

The 683 funded firms are located within the eight geographic regions of Mexico. Table 1 shows the states that are in each of the eight geographic regions.

Table 1. Regions of Mexico and the states within each region

North Region
Coahuila
Chihuahua
Durango
San Luis Potosí
Zacatecas
South Central Region
Ciudad de México
Hidalgo
México
Morelos
Puebla
Querétaro
Tlaxcala
Northeast Region
Nuevo León
Tamaulipas
Northwest Region
Baja California
Baja California Sur
Nayarit
Sinaloa
Sonora
Central West Region
Aguascalientes
Colima
Guanajuato
Jalisco
Michoacán de Ocampo
South Pacific Region
Chiapas
Guerrero
Oaxaca
Gulf of Mexico Region
Tabasco
Veracruz de Ignacio de la Llave
Yucatan Peninsula Region
Campeche
Quintana Roo
Yucatán

Fundamental to this paper is a measure of the innovative output from a PEI-funded project. In the CONACYT dataset, innovative activity is quantified through a self-reported variable that measures whether or not a new product, a new process, or a new service was introduced to the market from the year-long funded research project. We define the variable *Innovation* to equal 1 if the firm reported that it introduced at least 1 new product, new process, or new service to the market from its PEI-funded project and 0 otherwise.

Figure 1 shows, by geographic region, the percent of firms that were so defined as being innovative based on the information provided for their most recent PEI-funded project. Conspicuous in Fig. 1 is the relatively low innovation percentage rate in the South Pacific region when in fact, as shown in Fig. 2, the mean level of government research support to firms in that region is higher than in any other region. One possible explanation for this observation from Fig. 1 is that the South Pacific region is less economically well off than other regions, as measured in terms of the percent of the population that is classified as living in poverty, and thus, markets for new products, new processes, or new services are smaller and/or less developed so market innovations are in less demand in comparison to other regions in Mexico.[7] See Fig. 3.

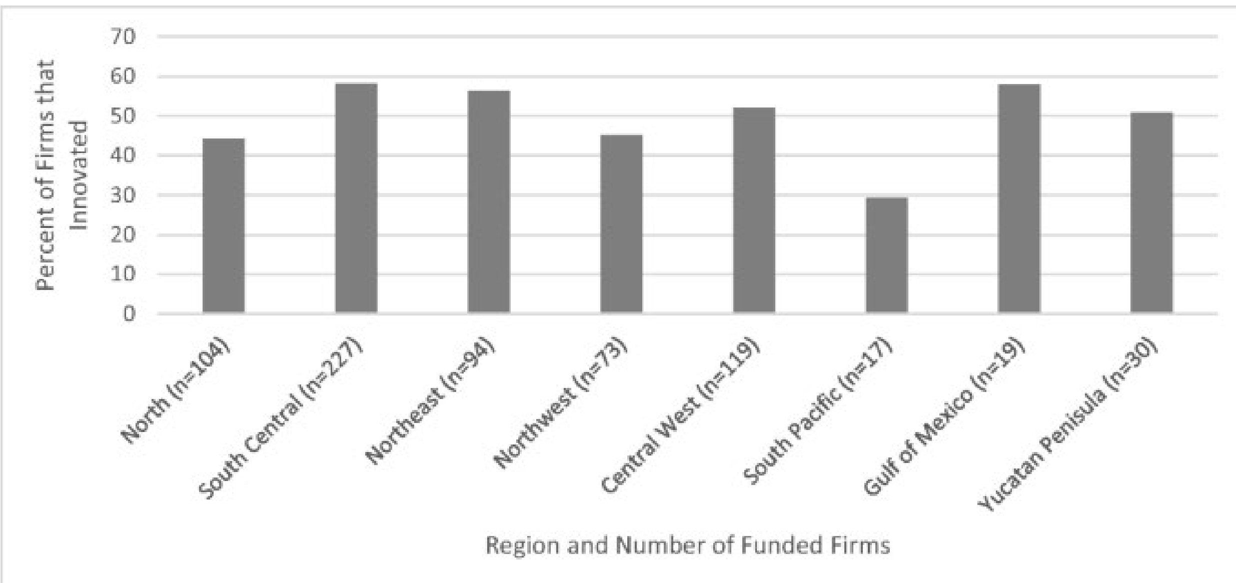

Fig. 1. Percent of PEI program–funded firms that innovated, by geographic region (*n*=683)

[7] The percent of the population in poverty is defined as the percent of the population that cannot buy the basic food basked with their work income. This definition comes from the code book for the PEI project data.

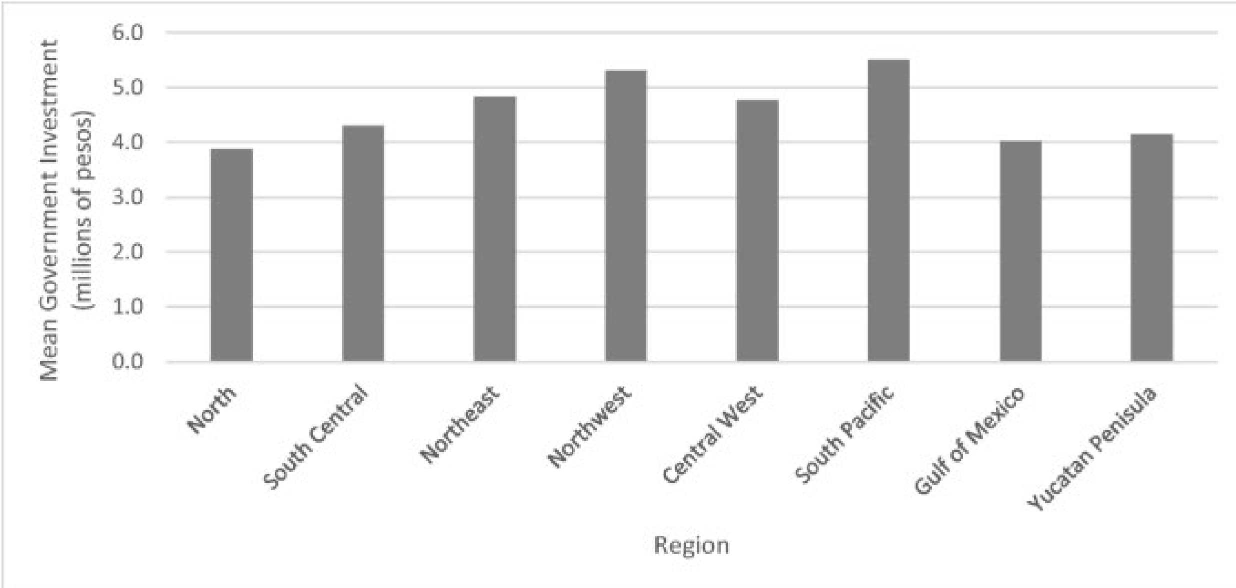

Fig. 2. Mean level of direct PEI program support to firms, by region (*n*=683)

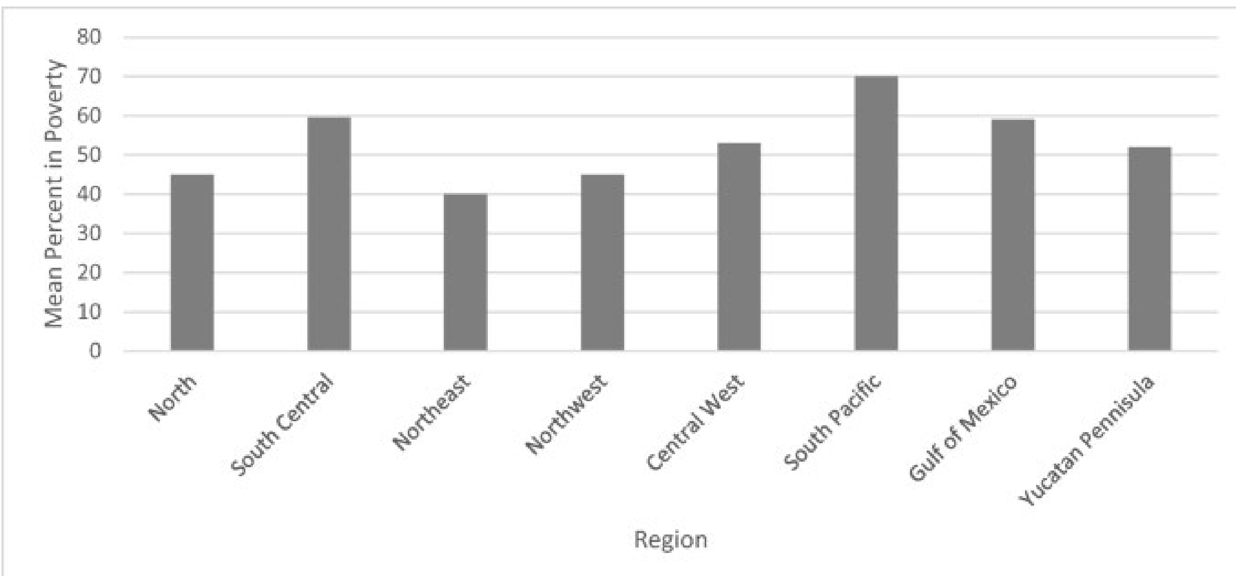

Fig. 3. Percent of population living in poverty, by region

Another possible explanation for the relatively low innovation percentage in the South Pacific region is related to the relatively large percentage of small PEI-funded firms in that region. As shown in Fig. 4, the South Pacific region has the largest percentage of small firms (i.e., firms with fewer than 50 employees; see the *Note* to Fig. 4) and the smallest percentage of large firms of any region in Mexico. The premise is that larger firms are more innovative due to a greater endowment of human capital and experiential capital (e.g., Link & Cunningham, 2021; Link & Oliver, 2020). The variable that is discussed below to quantify firm size is *Large firm*. *Large firm* equals 1 if the firm has more than 50 employees at the time of funding and 0 if not.[8]

[8] The actual number of employees was not available in the CONACYT data; only a categorical size variable was available.

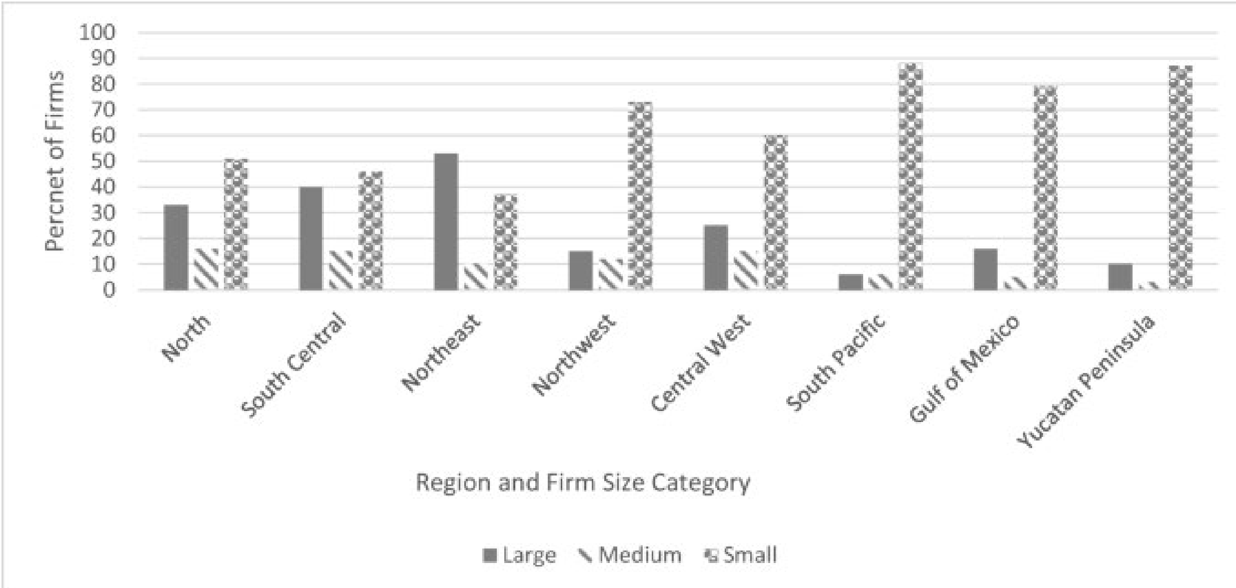

Fig. 4. Distribution of PEI-funded firms, by size of firm by region (n=683). *Note*: CONACYT defines a small or a micro firm, hereafter a small firm, as one with 50 or fewer employees, a medium sized firm is one with 51 to 250 employees, and a large firm is one with more than 250 employees

Given *Innovation* as the focal variable, that is a variable related to a market-based measure of the innovation success of the PEI program, there are other possible covariates with *Innovation* that are considered in this paper in addition to firm size.[9]

A second possible covariate with *Innovation* relates to prior innovation success. All of the firms in the sample had received at least one previous PEI research award. The number of previous awards in the sample ranges from 1 through 30. Information was provided as to the innovation success of the firms' previous research projects, that if a previous project resulted in an innovation as defined by *Innovation*. From this information, *Prior innovation success* is calculated as the number of previous PEI-funded projects that resulted in introducing to the market a new product, a new process, or a new service and 0 otherwise. To the extent that success breeds success, and building on prior research (Link & Ruhm, 2009; Link & Scott, 2009, 2010), we hypothesize a positive relationship between *Innovation* and *Prior innovation success*.

A third possible covariate with *Innovation* is the research budget for each firm's most recent PEI-funded project. There are three components to a firm's research budget. There is the firm's contribution; a research partner's (i.e., a university research partner's) contribution, which, in a few cases, is 0; and the direct contribution by the PEI program (i.e., the government's contribution), which was shown in Fig. 4. Based on the extant literature (e.g., Audretsch & Link, 2018a, 2018b; Bednar et al., 2021; Boles & Link, 2017; Gicheva & Link, 2016; Link et al., 2020; Link & Ruhm, 2009; Link & Scott, 2009, 2010; Protogerou et al., 2017) that a research

[9] The number of such variables is constrained by information in the CONACYT dataset provided to us.

budget is an input to a firm's (or an economic unit's) technical capital and thus an input related to its research success, we hypothesize a positive relationship between *Innovation* and the total research budget of the project, *Research Budget*.

A fourth possible covariate with *Innovation* relates to the percent of the research budget that is directly funded by university research partners, *University Percent.* The primary motivation for considering this variable is that encouraging research partnerships with universities is part of the purpose statement of PEI-funded research. It logically follows to ask the question about how such research partnerships affect innovative behavior. However, we do not hypothesize the directional relationship between *Innovation* and *University Percent*.

A final possible covariate relates to the firm's ability to acquire additional human capital during the research process. If the firm hires additional workers, which enriches the human capital base of the firm, one might expect, based on the extant literature (e.g., Link & Scott, 2009, 2010), that such greater human capital within the firm, *New Employees*, will be positively related to *Innovation*.

Table 2. Definition of variables

	Definition
Economic variable	
Innovation	=1 if the firm introduced to the market based on its most recent PEI funded project a new product, a new process, or new service; 0 otherwise
Large firm	=1 if the firm had at the time of its most recent PEI funded project more than 50 employees; 0 otherwise
Prior innovation success	=1 if the firm had precious research projects funded by PEI that resulted in an innovation (as defined by *Innovation*)
Research budget	= the total amount of research funding for the firm's most recent PEI funded project (millions 2014 constant pesos)
University percent	= the percent of total research funding for the firm's most recently funded project from university research partners
New employees	=1 if the firm hired any new employees during its most recent PEI funded project; 0 otherwise
Control variable	
R1 Dmy	=1 if the firm is located in the North geographic regions; 0 otherwise
R2 Dmy	=1 if the firm is located in the South Central geographic regions; 0 otherwise
R3 Dmy	=1 if the firm is located in the Northeast geographic regions; 0 otherwise
R4 Dmy	=1 if the firm is located in the Northwest geographic regions; 0 otherwise
R5 Dmy	=1 if the firm is located in the Central West geographic regions; 0 otherwise
R6 Dmy	=1 if the firm is located in the South Pacific geographic regions; 0 otherwise
R7 Dmy	=1 if the firm is located in the Gulf of Mexico geographic regions; 0 otherwise
R8 Dmy	=1 if the firm is located in the Yucatan Peninsula geographic regions; 0 otherwise
State population	=population in each state in millions based on the 2010 Mexican census
State population not in poverty	=*State Population* multiplied by the percent of a state's population that is classified as not living in poverty (see Fig. 3)
Information technology Dmy	=1 if the firm operates in the information technology industry; 0 otherwise
Food Dmy	=1 if the firm operates in the food industry; 0 otherwise
Chemistry Dmy	=1 if the firm operates in the chemistry industry; 0 otherwise
Farming Dmy	=1 if the firm operates in the farm industry; 0 otherwise
Automotive Dmy	=1 if the firm operates in the automotive industry; 0 otherwise

Each of these covariate variables is defined in Table 2 and is considered in the empirical analysis below. In addition, several control variables are considered. One set of controls examines regional effects, and another set of controls examines the industrial sector in which the firm operates.

Regional effects are controlled for in three ways. First, regional fixed effects are controls for through regional dummy variables such as *R1 Dmy* for firms in the North region and so forth; see Table 1 for the numbering sequence. Second, regional fixed effects are replaced by the population of the state, which proxies the size of the market, *State Population*. And third, regional fixed effects are replaced by the population in each state that lives in poverty, *State Population Not in Poverty,* which is also a proxy for the size of the market.

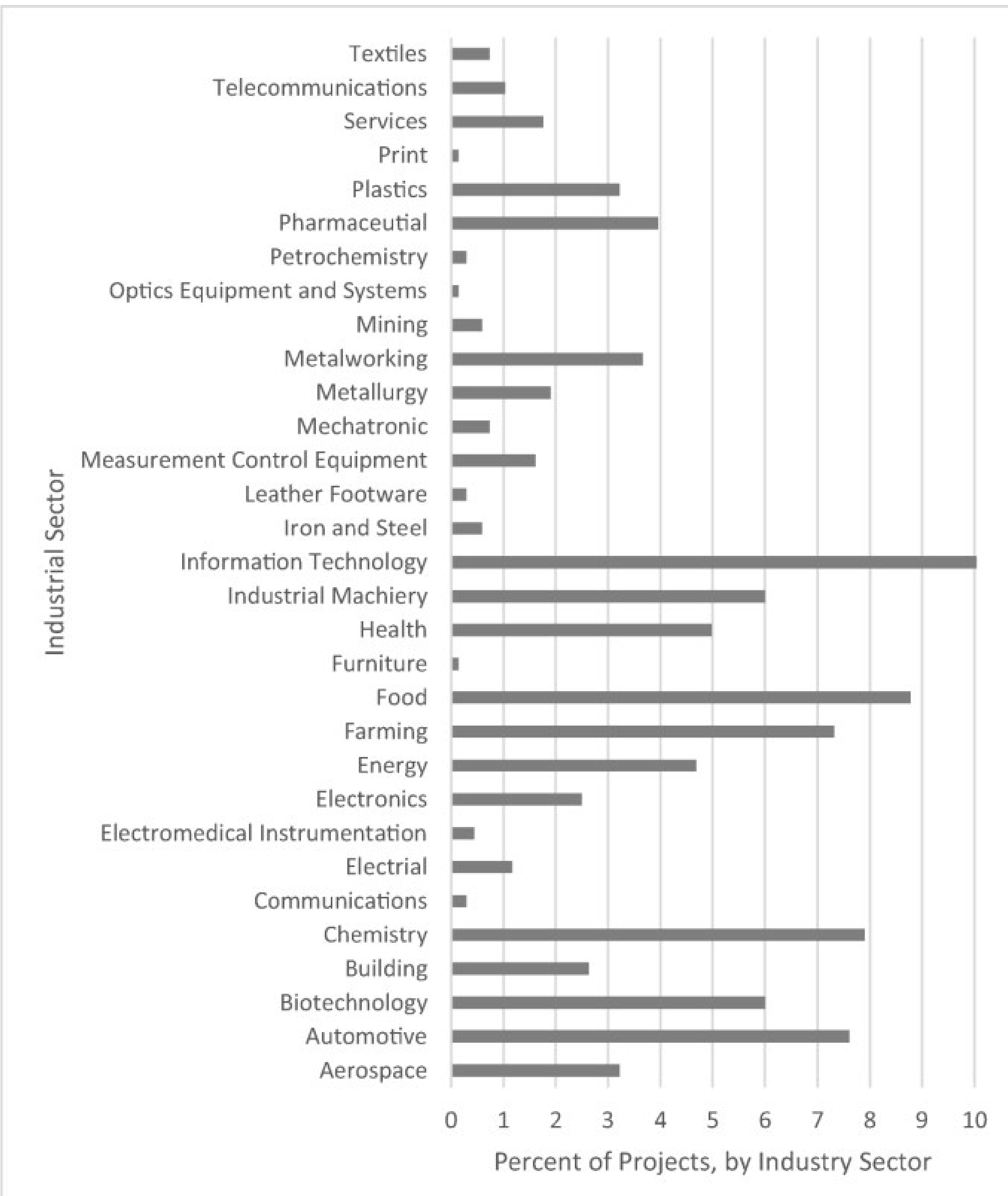

Fig. 5. Distribution of PEI-funded firms, by industry (*n*=683)

Table 3. Descriptive statistics on the variables in Table 2 (*n*=683)

	Mean	Standard deviation	Range
Economic variable			
Innovation	0.523	0.500	0/1
Large firm	0.455	0.488	0/1
Prior innovation success	0.621	0.486	0/1
Research budget	13.915	14.725	0.55–180
University percent	19.166	13.438	0–65.02
New employees	0.387	0.487	0/1
Control variable			
R1 Dmy	0.152	0.359	0/1
R2 Dmy	0.332	0.471	0/1
R3 Dmy	0.138	0.345	0/1
R4 Dmy	0.107	0.309	0/1
R5 Dmy	0.174	0.380	0/1
R6 Dmy	0.025	0.156	0/1
R7 Dmy	0.028	0.165	0/1
R8 Dmy	0.044	0.205	0/1
State population	5.132	3.527	0.64–15.18
Poverty	52.010	7.968	40–70
Information technology Dmy	0.157	0.364	0/1
Food Dmy	0.088	0.283	0/1
Chemistry Dmy	0.079	0.270	0/1
Farm Dmy	0.073	0.261	0/1
Automotive Dmy	0.076	0.265	0/1

Figure 5 shows the distribution of firms by their industrial sector. The five industrial sectors most highly represented are information technology, food, chemistry, farming, and automotive. Industrial fixed effects are controlled for through the variables *Information Technology Dmy*, *Food Dmy*, *Chemistry Dmy*, *Farming Dmy*, and *Automotive Dmy*.

Descriptive statistics on all of the variables are in Table 3.

Empirical analysis

The marginal effects associated with three probit models are presented in Table 4. The results in column (1) relate to the model with regional fixed effects, the results in column (2) relate to the model that replaces regional effects with the population of the state in which the firm is located, and the results in column (3) relate the population of the state in which the firm is located with the population of the state that does not live in poverty.

Table 4. Marginal effects from probit regression models (*n*=683), dependent variable = *Innovation*

Independent variable	**(1)**	**(2)**	**(3)**
Large firm	0.054*	0.054*	0.054*
Prior research success	0.025****	0.025****	0.025****
Research budget	0.001	0.001	0.001
University percent	0.002*	0.002*	0.002*
New EMPLOYEES	0.403****	0.403****	0.403****
R1 Dmy	−0.064	--	--
R2 Dmy	−0.008	--	--
R3 Dmy	−0.014	--	--
R4 Dmy	−0.071	--	--
R5 Dmy	−0.026	--	--
R6 Dmy	−0.139	--	--
R7 Dmy	0.058	--	--
State population	--	0.006	--
State population not in poverty	--	--	0.015
Information technology Dmy	0.019	0.019	0.019
Food Dmy	−0.038	−0.038	−0.038
Chemistry Dmy	0.089	0.089	0.089
Farm Dmy	0.044	0.044	0.044
Automotive Dmy	−0.059	−0.059	−0.059
Pseudo log-likelihood	−367.19	−368.26	−368.20
Wald χ^2	183.35****	182.61****	182.70****
Pseudo R^2	0.221	0.221	0.221

Note: **** significant at .01-level, *** significant at .05-level, ** significant at .10-level, * significant at .15-level

The three probit specifications are robust in terms of the size of the estimated marginal effects and their significance.[10] Large firms are more innovative than small firms, as hypothesized, although the estimated marginal effect is only marginally significant.

Prior research success is related to innovative activity. The estimated marginal effect of *Prior Research Success* is positive, as hypothesized, and it is highly significant. Contrary to our hypotheses and to segments in the R&D-to-innovation literature (e.g., Link & Scott, 2009, 2010), the size of a firm's project research budget is not significantly related to the firm's innovative activity. One interpretation of this findings is that research success breeds research success. However, to the extent that the firm's prior research success is related to its currently funded project, the firm's future innovative research might similarly follow. Thus, in a path-dependent manner, in the sense of Nelson and Winter (1982), the firms' efforts toward future entrepreneurial actions might be dampened.

Although we did not offer a hypothesis about the directional relationship between the percent of the project's budget that came from universities, the estimated marginal effects are positive, and they are marginally significant in the specifications reported in columns (2) and (3). To the

[10] In separate models, *Research Budget* was measured as a natural logarithm to account for non-linearity, but the estimated marginal effects were not significant at a conventional level. These results are available from the authors on request.

extent that collaboration with a university represents an expansion of the firm's entrepreneurial ecosystem, the firm's future entrepreneurial insight might be broadened (Cho et al., 2021).[11]

Those firms that added employees to their research project are also those firms that were more innovative, as hypothesized. The estimated marginal effects on *New Employees* is positive and highly significant.

Finally, none of the regional or industrial control variables is significant, although the estimated marginal effect of *State Population* (column (2)) and *State Population Not in Poverty* (column (3)) is positive and significant at the 0.20-level.

Concluding remarks

This paper is the first systematic study of the innovation impact of a government-sponsored research program in a developing country, Mexico.[12] As such, our findings should be interpreted with caution for at least three reasons. First, there are no other empirical studies to which to compare our findings. Second, the CONACYT data made available were limited in the scope of how an innovation was defined. And third, data were available only on funded research projects so no comparisons to unfunded projects were possible.

Caveats aside, our findings compare well with other studies of government-sponsored research. To summarize, we found that large firms are more innovative than small firms. And, firms that are more innovative are those that had prior research, collaborated with universities in the funded research project, added new employees during the research project, and faced larger markets for their innovations.

To the extent that policymakers associate innovative activity with economic growth and development in their country, other countries similar to Mexico might view the PEI funding program to be a viable element of growth strategy.[13] And if they do, the findings in this paper might provide an initial indication about those firms that will have a greater innovation-related response to the public funding to support their research.

Acknowledgments

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[11] Perhaps, and this is beyond the scope of this paper, a firm that expands its entrepreneurial ecosystem might, purposively or not, develop an economic force that offsets any narrowing of its entrepreneurial actions associated with its tendency to pursue a path dependent research agenda. Relatedly, see de Fuentes et al., (2021).

[12] There are other studies of the impact of publicly funded research on innovative behavior in developed countries. See for example, studies related to the U.S. Small Business Innovation Research (SBIR) program: Audretsch et al., (2002); Leyden and Link (2015); Link and Oliver (2020); and Link and Scott (2010). Relatedly, see Link (2021) on innovations resulting from publicly funded R&D performed in U.S. federal laboratories.

[13] See, for example, Goel and Nelson (2021) for a multinational analysis in which Mexico is one of the countries considered.

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