ILAS SIPA Fellowship, Argentine Study Program

Rethinking industrial policies for Argentina: fostering innovation and entrepreneurship[1]

Pablo Sanguinetti
Universidad Torcuato Di Tella
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Abstract

Like many other Latin American and Caribbean (LAC) countries, Argentina must boost productivity growth to pursue a more dynamic development path. A key factor in achieving this is promoting innovation and entrepreneurship. This paper first examines government programs that provide grants, tax incentives, and concessional loans for innovation and R&D projects, primarily targeting existing firms. It then analyzes public funding for universities and research institutions. These grants and budget allocations can influence private-sector innovation and productivity through spillover effects, such as technology transfer and public-private collaboration to build science-based enterprises. While the first set of policies has positively impacted firm-level innovation, employment, and sales, their effectiveness could be enhanced by supporting privately run incubators, accelerators, and venture capital organizations. Looking at the case of the biotechnology sector, we document how these actors have recently played a pivotal role in collaborating with public research institutions and advancing science-based startups targeting regional and global markets.

1. Motivation and objectives of the study.

Latin America and the Caribbean (LAC), particularly Argentina, have significantly lagged in economic growth compared to other developing regions like Southeast Asia or Eastern Europe. This disparity has led to a slow rate of income convergence with developed economies. For instance, the average income per capita was approximately 0.20 of that of the USA in 1960 and only increased to 0.26 in 2010-2014 (Sanguinetti et al., 2018). In the case of Argentina, the decline was even more pronounced: this country's income per capita was about 0,75 of the USA before WWI and dropped to 0,35 a century later (Jones, 2015). Most growth accounting exercises (Sanguinetti et al., 2018) indicate that weakened productivity dynamics are the primary cause of the lack of convergence in income per capita. In simpler terms, the LAC countries, especially Argentina, need to enhance their efficiency in resource utilization at the firm level, sectors, and aggregate economy.

In the last 15 years, there has been a flourishing literature looking at the immediate forces behind this sluggish productivity growth in developing economies and LAC, in particular. One channel that has been emphasized is the problem of misallocation. The difference in productivity across countries is partly associated with substantial productivity disparities across firms, even within narrowly defined sectors, caused by distortionary policies (taxes, regulations, subsidies, etc.) and/or market failures (financial frictions, innovation spillovers, see below). These factors disproportionately affect high-productivity enterprises or entrepreneurs while, at the same time, promoting the survival of small, informal, low-productivity firms that absorb a large portion of the resources of the economies (Banerjee and Dufflo, 2005; Restuccia & Rogerson, 2008).

A second channel is that even formal firms in Latin America and Argentina have low productivity compared to developed economies. Thus, a focus must be placed on factors that disincentivize the

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innovative efforts of firms throughout their life cycle, including the initial entrepreneurship stage when they are created. Failures in these innovation processes explain why formal enterprises in the region do not grow as much as in developed economies, keeping them relatively small (Hsieh and Klenow, 2014). The evidence about the relative importance of these two channels -misalignment vis poor selection/innovation- for the manufacturing sector in various LAC countries shows that the last factor plays a critical role (Sanguinetti et al., 2018).

In the context of these findings, this paper examines some policy options that Argentina could design and implement to foster entrepreneurship and innovation and, thus, productivity. This will be our approach to industrial policy, contrasting with the more traditional and often failed practices of protectionism, indiscriminate subsidies, and cheap loans. As mentioned above, when looking at the productivity consequences of innovation policies, we will not only concentrate on the impact on existing firms, but a very relevant mechanism is to what extent the innovation and R&D initiatives (private and public) generate a robust entrepreneurial activity with the launching of start-ups that are the result of collaboration among scientists, entrepreneurs, and investors.

Among the various policy options to foster innovation and productivity that have been identified in the policy literature (see Crespi et al., 2016; Navarro and Olivari, 2016; Bloom et al., 2019; Cepal, 2022), we will focus on two instruments. First, government programs offering grants, tax subsidies, and concessional loans for innovation and R&D projects carried out by (mainly existing) firms. Second, we will examine the government's grants to universities and public research centers. We will argue that these grants and budget allocations to finance research in these institutions could also affect private-sector innovation and productivity through spillover effects via, for example, technology transfers and public-private collaboration to create science-based startups.

In the analysis of these two policy instruments, we follow different methodologies. Regarding innovation grants to private firms, we will use a newly available data set that merges the last three editions of the innovation survey for the manufacturing sector in Argentina. We will run an econometric exercise that will try to quantitatively estimate the impact of public support on various innovation input and output indicators at the firm level. Concerning the public money going to public universities and research centers to finance R&D and science in general, we will adopt a more qualitative methodology, describing the main actors in the public scientific ecosystem and the different initiatives that have been put into place for promoting spillovers in terms of technology transfer and science-based start-ups. We will gauge the effectiveness of these measures by a case study that looks at the biotechnology sector. The interaction between science and private interests has been very relevant in this industry in recent years.

2. Government tax incentives and grants to private firms[2]

In this section we will adopt a broader approach to innovation performed by firms that go beyond R&D and include the acquisition of machinery and equipment, information and telecommunications technologies (e.g., software and hardware development), innovation in marketing methods, technology transfer (e.g., purchasing of licenses), technical assistance and consulting, engineering and industrial design, improved management techniques, and education and training (R+D+i). The availability of innovation surveys in many LAC countries has greatly benefited the analysis of all these items of innovation activities. In the case of Argentina, a novel data set recently made available by the National Agency of Innovation and Technology links the last three editions of the Innovation Survey (EDITs). This allows for constructing a panel dataset that follows the same firms from 2012 to 2021. This will

[2] This section of the paper is based on Sanguinetti and Feroce, 2024.

significantly enhance the possibility of understanding the enterprises´ decisions about innovative activities.

The classical public finance solution to the problem that private innovation expenditures have positive externalities and may be lower than socially optimal would be subsidizing the economic activity that creates the positive externality, i.e., private innovation investment. Two policy tools available are tax credits and direct subsidies. These direct subsidies can be allocated through no reimbursable funds or concessional loans. Tax incentives are a more market-oriented approach, leaving decisions on the level and timing of the investment to the private sector. At the same time, in the case of grants and concessional loans, the government can direct them to those activities where spillovers and other market failures (like credit restrictions) are more significant.

In Argentina and the rest of the region, the most widely used mechanism is competitive funds that co-finance, with non-reimbursable resources, R+D+i projects presented by companies. These are horizontal funds with no sectoral or thematic priorities, allocated based on criteria such as the project's level of innovation, potential commercial value/economic impact, and expectations of financial sustainability[3]. Sectoral or thematic funds often complement these horizontal programs[4]. Most of these programs have a particular focus on SME firms.

Argentina has applied different initiatives in the last 30 years to promote investment in R+D+i in private firms. The variety of policy instruments is significant and reflects the aim of solving market failures that may hinder innovation. Besides spillover effects, there is the problem of financial frictions, so grants or concessional loans have also been designed to address this problem[5]. There is also the potential problem of coordination failures that preclude the formation of dense client-supplier productive chains or cluster-type productive developments. Various programs have been designed to solve these other market failures[6].

Using the above-mentioned database, we will summarize some critical indicators of firms' innovation activity and the coverage of public support across production units and provide new results of the impact evaluation of these initiatives in terms of innovation inputs (say, private innovation expenditure, patent application, etc.) and outputs (say, employment, sales, and productivity)[7].

2.1 Firm-level innovation input and output indicators for Argentina.

Like other countries in the region, Argentina has been tracking innovation efforts and initiatives taken by private firms in the manufacturing sector by implementing innovation surveys. The first survey was conducted in 1999 and has been followed by new editions every three years. The Secretary of Science,

[3] For example, FONTAR -Plan Argentina Innovadora 2020; FINEP/FNDCT - Programa de Subvenção Econômica in Brazil; FIC: Fondo de Innovación para la Competitividad in Chile; Minciencias - Locomotora de la Innovación para Empresas in Colombia; CONACYT - Fondo de Innovación Tecnológica in Mexico.

[4] These are justified by "Mission-type" arguments (Mazzucato, 2021). See, for example, FONTAR- Aportes No Reembolsables Producción Más Limpia (ANR P+L) for the case of Argentina and FINEP- INOVA ENERGIA in Brazil.

[5] FONTAR - Créditos para la Mejora de la Competitividad (CRE CO) is an example of a concessional loan program for supporting R+D+i.

[6] See, for example, FONTAR - Fortalecimiento de la Innovación Tecnológica Proyectos de Desarrollo de Proveedores and FONTAR- Proyectos Integrados de Aglomerados Productivos (PITEC).

[7] In the last 20 years in Latin America, a wealth of works has tried to quantitatively evaluate the impact of these programs on firms' outcomes. See Sanguinetti (2005) and Lopez et al., (2010) for the case of the FONTAR program in Argentina.

Innovation, and Technology has recently released a database linking the last three editions of the survey (2012-2014, 2014-2016, and 2019-2021) for a sample of around 760 firms. In this section, we will use this data set to describe some innovation input and output indicators during the 2012-2021 period. The following section uses this data to perform an impact evaluation analysis of various government support programs.

Firms' basic characteristics

We start by describing some basic features of the firms in the database. Table 1 depicts for each year of the sample and the entire period the mean value for the number of employees by firm, total sales (expressed in pesos of 2010), and the share of workers with university degrees. Considering all the years, the average size of the firms is 267 workers, while sales were 265,6 million pesos (equivalent to 68 million dollars). On the other hand, university degree workers make up around 8,6% of the labor force. The evolution of mean workers per firm and mean total sales throughout the period shows fluctuations partly related to macroeconomic conditions. Pick values are observed in the expansionary years of 2011 and 2012, while drastic falls occurred in 2019 due to a protracted economic crisis that started in 2018. Then, in 2020, the pandemic negatively affected the economy and firms' cash flow. In the case of the human capital indicator, we observe an increasing trend during the period.

Table 1. Firm's basic indicators.

Variable/year	2010	2011	2012	2014	2015	2016	2019	2020	2021	Mean
employees	267,83	280,92	282,14	278,71	279,9	271,42	244,82	246,81	253,34	267,11
sales (millions pesos of 2010)	245,7	270,3	276,5	276,6	253,1	253	264,8	250,0	307,2	265,6
% of skilled workers	7,13%	7,26%	7,68%	7,83%	7,93%	8,48%	10,08%	10,26%	10,61%	8,59%

Source: ENDEI 2024.

Table 2 shows the size distribution of firms considering employment. We divide firms into three categories: small (10-50); medium (51-200), and large (+200). In all years, small firms are more numerous than medium and large firms, representing, on average, 45% of the sample, followed by medium (33%) and big enterprises (22%). These proportions are inverted when considering the share in total employment by size category (not shown), with large firms encompassing around 40% of the workers across all years of the sample, followed by medium (35%) and small (25%) firms.

Table 2. Size composition of firms.

Year/size category*	Small (10-50)	Medium (51-200)	Large (+200)	Total
2010	348	196	182	726
2011	342	205	188	735
2012	336	206	190	732
2014	341	195	187	723
2015	337	201	197	735
2016	338	203	188	729
2019	355	213	185	753
2010	359	212	182	753
2021	346	216	188	750
Average	344,7	205,2	187,4	737,3

* Few micro firms (less than 10 employees) have been excluded. Source: ENDEI 2024

Innovation input indicators

Table 3 describes some innovation input indicators. We look at total innovation expenditures (in millions of 2010 pesos), their share in total sales, the share of workers allocated to innovation activities, and the proportion of firms that report positive innovation expenditures. The mean value of innovation expenditures for the sample was more than 4 million pesos (around one million dollars), representing 1.87% of total sales. On average, the number of workers allocated to innovation activities represented less than 1% of total employment, and 60% of the firms allocated resources to innovation. The temporal evolution of these indicators shows that the pandemic strongly affected innovation efforts. Expenditures in this activity fall in absolute terms and relative to total sales. This was partly due to a decline in the intensive margin (firms that reported positive expenditure in 2020 and 2021 decreased their outlays) and the extensive margin as firms that allocate resources to this activity fell from 72% in 2019 to 38% of the sample in 2020 and 42% in 2021[8].

Table 3. Innovation inputs indicators.

Variables/years	2010	2011	2012	2014	2015	2016	2019	2020	2021	Mean
Innovation expenditures (millions pesos of 2010)	3,39	4,44	3,49	3,6	5,87	5,02	3,98	3,37	3,95	4,11
Innovation expenditures/total sales	0,0212	0,0218	0,0235	0,0218	0,0222	0,0221	0,0135	0,0106	0,0128	0,0187
% of employees in innovation activities	0,65%	0,62%	0,68%	1,61%	1,59%	1,73%	0,61%	0,52%	0,65%	0,90%
% of firms with positive Innovation expenditures	68%	70%	71%	69%	72%	72%	37%	38%	42%	60%

Source: ENDEI 2024

As mentioned, the innovation expenditure indicator includes various categories: internal and external R&D, Hardware/Software, Machinery and Equipment, Design, Consulting, Transfer of Technology (licenses), and Training. Table 4 presents the share of expenditures of each item within total innovation outlays for each year and the complete period. We see that R&D performed within the firm (internal R&D) is not necessarily the most relevant item. An essential channel through which Argentinian firms introduce innovation of products and processes is the purchase of machinery and equipment. This represented a share of almost 38% of total innovation expenditure for the entire period. The second most important item is internal R&D, with a 13.2% share, followed by industrial design with 9%.

Table 4. Innovation categories.

Innovation item %/year*	2010	2011	2012	2014	2015	2016	2019	2020	2021	Mean
Training	2,4%	2,2%	2,4%	1,9%	2,3%	2,4%	1,2%	1,3%	1,5%	1,9%
Consulting	5,0%	5,2%	6,5%	5,6%	5,6%	5,5%	ND	ND	ND	4,1%
Design	8,0%	9,7%	8,3%	15,1%	15,0%	15,4%	5,4%	4,6%	4,7%	9,0%
Hard/Software	6,1%	6,7%	6,3%	7,1%	7,3%	7,6%	2,3%	2,7%	2,8%	5,2%
External R&D	3,3%	3,0%	3,7%	3,1%	2,6%	2,2%	0,7%	0,4%	0,7%	2,1%
Internal R&D	13,5%	14,3%	16,0%	17,8%	17,1%	16,6%	8,9%	8,8%	8,9%	13,2%
Machinary	44,6%	45,2%	46,2%	49,4%	50,3%	49,7%	19,0%	20,7%	23,3%	37,9%
Tech. transference	1,6%	1,2%	1,2%	0,9%	0,9%	0,8%	0,4%	0,3%	0,4%	0,8%

*The sum of all innovation items is not 100% due to missing information. Source: ENDEI 2024

[8] The low value in 2019 is somewhat biased downward because of it was obtained by a backward estimation firms provided when interviewed in 2021.

Innovation output indicators

One last set of variables we would like to look at is those associated with innovation outputs. These are indicators related to what firms report about the results of their innovation efforts. We have selected three indicators: the percentage of firms that report having improved or developed a new product, the percentage of firms that improved or developed new production processes, and finally, whether these new products or production processes have been associated with adopting some intellectual property mechanisms like patents, trademarks, etc.

Table 5 shows the mean values of these indicators for the complete sample period and the three time periods corresponding to each edition of the innovation survey (there is a unique value for these indicators covering the three years of each survey edition). Many firms (65%) report positive innovation results in products, processes, or both. This value was 46% during the pandemic, while around 75% in the previous years. Also, 44% of firms established some intellectual property protection mechanism, of which patents comprised approximately 17%.

Table 5. Innovation outputs indicators.

Variable/ year	2010-2011-2012	2014-2015-2016	2019-2020-2021	Mean
% of firms reports new or improved products	64,89%	66,44%	34,34%	55,16%
% of firms reports new or improved processes	63,82%	62,86%	27,89%	51,45%
% of firms report new/improved product or process	73,40%	75,72%	46,05%	65,00%
% of firms with some intelectual property protection	51,40%	51,56%	31,09%	44,64%
Of those, % of firms with patents	20,62%	20,10%	6,89%	17,22%

Source: ENDEI 2024

Innovation activities were a relatively common task for the sample of firms in the data set. Not only do they allocate funds and human resources to these activities, but a high proportion of them report positive innovation results partly protected by some intellectual property instrument. Below, we will see whether government support programs were a reason behind this pro-innovation drive and whether they impacted firms' performance.

2.2 Quantitative evidence on the impact of public support programs

To develop some quantitative exercises to gauge the impact of government support programs, we will apply Difference-in-Difference (DID) estimation methods. Since these government subsidies and concessional loans are not granted randomly, beneficiaries may differ from non-beneficiaries due to selection bias. For example, beneficiaries are more likely to be innovative (investing in R&D and other innovation activities) and more productive than non-beneficiaries. Therefore, beneficiaries would show different outcomes than non-beneficiaries even without program support. A significant advantage of using longitudinal firm-level datasets is that introducing fixed effects at the firm level allows for controlling constant unobservable factors that may affect both the outcome of interest and participation in the program. In addition, to avoid further potential endogeneity biases due to important differences in the treated and control group characteristics, we run the estimation not only for the whole sample of firms but also using a more restricted dataset constructed by applying the Propensity Score Matching (PSM) methodology[9][10]. The equation that we will estimate has the usual specification of DID format,

$$Y_{ijt} = \alpha + \beta D_{it} + \delta_t + \mu_i + \delta_t * \theta_j + \epsilon_{ijt}$$

Where Yijt is the variable of interest associated with firm i belonging to sector j in time t. Dit is the policy variable that defines if a firm participates in any of the government programs that promote innovation, δt is a time fixed effect, μi is a firm fixed effect, δt* θj is a multiplicative year-sector dummy that captures time-variant shocks at the sector level, and ϵijt is an error term assumed to be uncorrelated with Dit.

As we indicated above, we will test the impact of government support on various input and output indicators and firm performance variables collected in the innovation surveys. (i) input variables: total innovation expenditures and labor allocated to these activities; (ii) output variables: improved and new products and production processes, intellectual property protection instruments like patent applications; (iii) firms' performance: total sales, employment, and labor productivity.

To estimate the regression in equation (1), we would use the policy variable Dit, which takes the value of one since the first year the firm participated in government programs. This specification for the policy variable will be applied to innovation expenditures and all the other innovation indicators. The rationale for this specification is that it could take some time for these variables, including the firm's performance metrics, to react to the government support initiatives[11].

The last issue we must explain is the particularities of the government programs we use as explanatory variables. We propose to include in one category, called FFC, the most important programs managed by the National Agency for Technology and Innovation: FONTAR, FONACER, and COFECYT. FONTAR (Fondo Tecnológico Argentino) is the most well-known program, established in 1998, and has a horizontal approach to financing R&D, technological updates and services, and innovation capabilities within firms[12]. FONARSEC (Fondo Nacional Sectorial) has a more thematic or sectoral approach to promoting innovation and technology development through public-private or private-private collaboration in health, energy, agribusiness, biotechnology, and environment/climate change subjects[13]. Finally, the COFECYT (Consejo Federal de Ciencia y Tecnología) program offers financing lines to promote activities to develop and strengthen science, technology, innovation, and knowledge transfer in all provinces and regions of Argentina. These programs channel innovation funds through grants, credit lines, and tax subsidies.

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[9] To apply the PSM method, we used data from 2010, dropping firms treated (received government subsidies) that year. We estimate a probit model using the total number of employees, total sales, total innovation expenditures, number of university-educated workers, and sector dummies as controls. The dependent variable is a dummy indicating whether the firms received public support in any year between 2011 and 2021. See details of this estimation in Sanguinetti and Feroce (2024).

[10] In Sanguinetti and Feroce (2024), we also ran the regressions for the sample of firms that reported positive innovation expenditures for at least one year during the considered period. The results do not differ from those described below.

[11]In Sanguinetti and Feroce (2024) regressions, the policy variable also includes the amount of resources in levels and logs. This allows us to evaluate the "additionality" hypothesis (whether public funds crowd in or crowd out private innovation expenditures).

[12] Generally, Fontar prioritizes small and medium-sized companies (Arza et al., 2018; Fiorentino et al., 2019). There are not publicly available sources that describe the amount of resources allocated to this fund, but between 1997 and 2007, the Agency subsidized almost 9,000 projects, allocating over 1,300 million Argentine pesos (approximately USD 400 million at that time). See Lopez et al 2010.

[13] The particular initiatives through which this collaboration took place will be analyzed in detail in the next section.

Before running the regressions, it is worth noting that during 2010-2012, nearly a quarter of the firms in the sample participated in one or more of the aforementioned government support programs. This take-up rate fell to close to 12% in the second survey (2014-2016) and decreased even further (7.6%) in the last survey edition (2019-2021). For the whole period, around 14.5% of the firms received funds from government initiatives for at least one year.

Innovation input regressions: expenditures and R+D+i workers

Table 6 presents the regression results for innovation inputs, looking at expenditure and labor allocated to R+D+I activities. As explained above, the policy variable is a dummy that takes the value of 1 starting at the year the firms receive public support for the first time. Regarding (logs) expenditures, we see that the estimated coefficient for the FFC policy indicator is 3.12 for the whole sample, implying that participating firms increase innovation expenditure by over 300% compared to those that do not participate. The results do not change much when using the PSM sample. Thus, the government program positively impacted innovation outlays in participating firms. Another innovation input variable is associated with workers allocated to R+D+i. Before we showed that, on average, firms allocated 3% of their labor force for these activities. The last two columns of Table 6 investigate whether firms that participated in government programs have increased the number of employees in innovation activities. The results suggest that firms participating in FFC programs increased human resources in R+D+i by almost 50%, with minor differences across the regression samples.

Table 6. Regressions for innovation inputs: innovation expenditures and labor allocated to R+D+i

	Expenditures (logs)		**Labor (logs)**	
	Complete sample	Common suport using PSM	Complete sample	Common suport using PSM
Dummy participation in FFC funds	3,12***	3,00***	0,49**	0,48**
z	0,92	3,30	2,46	2,38
Sector-Year Dummies	YES	YES	YES	YES
Whitin R2	0,0010	0,2294	0,1448	0,1603
Between R2	0,2283	0,0431	0,0043	0,0017
Overall R2	0,0189	0,1333	0,0383	0,0474
Total Obs	6492	5582	6668	5693
# of Groups	760	649	760	649
Average obs per group	8,54	8,60	8,8	8,8

z: robust standard errors clustered at the firm level. *** significant at 1%; ** significant at 5%; * significant at 10%

Innovation output regressions: new or improved products or production processes and patents

Now, we look at innovation outputs. We will concentrate on two indicators: whether the government support programs effectively promoted the improvement or development of new products or production processes, and if these innovations results have been associated with registering new patents. Regarding the first indicator, we have shown that the percentage of firms reporting doing so has been relatively high, around 65% across all years. Table 7 shows that those firms that participated in government support programs tend to have a higher inclination to innovate as the coefficient for the FFC policy variable is positive and significant (close to 95% confidence). We obtain very similar results when using patents as a dependent variable; even the estimated coefficients are of about the same magnitude[14].

Table 7. Regressions for Innovation outputs

	Product and process innovation		Patents	
	Complete sample	Common suport using PSM	Complete sample	Common suport using PSM
Dummy participation in FFC funds	0,12**	0,12**	0,13***	0,12**
z	1,90	1,95	2,64	2,55
Sector-Year Dummy	YES	YES	YES	YES
Whitin R2	0,1655	0,1700	0,0803	0,0739
Between R2	0,0041	0,0176	0,0606	0,0676
Overall R2	0,0849	0,1017	0,0708	0,0713
Total Obs	6498	5826	6672	5718
# of Groups	760	649	760	649
Average obs per group	8,55	9.0	8,8	8,8

z: robust standard errors clustered at the firm level. *** significant at 1%; ** significant at 5%; * significant at 10%

Firms´ performance indicators: sales and employment

We now present a set of regressions that attempt to evaluate the impact of innovation support policies on firms' performance variables: sales and employment. Table 8 shows the estimation results for the two indicators. For total (log) sales (including both domestic and external markets), we observe that the FFC program participation variable has a positive and significant (at a 5% confidence level) effect, increasing sales by approximately 24% compared to non-participating enterprises. We also find a positive impact on firms' labor force by around 18%. Again, as in previous estimations, these results do not change much when we restrict the sample to firms that share a common support determined by the PSM estimation.

Table 8. Regressions for firms´ performance variables

	Total sales (logs)		Total employment (logs)	
	Complete sample	Common suport using PSM	Complete sample	Common suport using PSM
Dummy participation in FFC funds	0,24**	0,25**	0,18**	0,19**
z	2,16	2.21	2,41	2,45
Sector-Year Dummies	YES	YES	YES	YES
Whitin R2	0,0896	0,1024	0,0918	0,1040
Between R2	0,0094	0,0036	0,0003	0,0018
Overall R2	0,0001	0,0003	0,0021	0,0041
Total Obs	6,727	5,761	6,686	5753
# of Groups	760	649	760	649
Average obs per group	8,9	8,9	8,8	8,9

z: robust standard errors clustered at the firm level. *** significant at 1%;
** significant at 5%; * significant at 10%

[14] Given the linear regression specification applied to a dichotomic dependent variable, we cannot give a precise interpretation of the estimated coefficient in both cases.

Heterogeneous impact

A final exercise that could be interesting to explore is whether the estimated impacts we have shown so far differ in terms of some characteristics of the firms before treatment (we will take that to be the initial year of the sample). Due to its relevance to the second part of the paper, we selected two unique features: the firm's age and the level of education of the workforce. For the first variable, we divided the sample into three groups: start-ups (A1: age 1-5 years), medium-aged firms (A2: 6-20), and mature enterprises (A3: +20). Regarding human capital, we divide the sample into three terciles using the share of university degree employees, starting with group H1 (the one with the lowest share of university employees) and groups H2 and H3, where this share increases.

As we will explain in more detail in Section 3, these two features are relevant to investigating how innovation activities are implemented within firms and to what extent government support can achieve positive results in the various indicators we have observed. Young firms may face more difficulties financing innovation projects due to their short production records and presumably smaller size and material asset acquisition (compared to intangible property). Thus, the impact of public programs on their decision to innovate could be higher. On the other hand, without proper monitoring and advice, younger firms are less experienced in dealing with the required information and the bureaucratic processes associated with participating in competitive calls for innovation subsidies, and perhaps even more important, how to convert a business idea or a scientific discovery into a viable commercial product or service. Concerning human capital, we may expect that firms with an initially more qualified labor force are more likely to engage in innovation activities and take advantage of government support programs. As we will see below, this may be the case for firms utilizing new technologies, such as science-based start-ups.

Table 9 presents the regressions for various innovation input, output, and performance indicators, incorporating the interaction of firm age. We present the results only for the complete sample specification, as no significant differences exist when using the PSM sample. Regarding innovation expenditures, we observe that the coefficient for the FFC fund is positive and statistically significant for the three groups of firms; however, the effect appears to be more pronounced for the oldest group. The results for the other innovation indicators, or firms´ performance variables, do not always follow this pattern. For example, self-reported innovation outcomes (new or improved products or production processes) tend to be slightly more significant in older firms. However, this is not the case for labor allocation to R&D and innovation activities and total sales, where we find positive and more significant impacts for start-up firms.

Table 9. Heterogenous impacts by firm´s age

Dependent Variable	Total Innovation Exp (logs)			Labor allocated to I+D+i (logs)			Products and Processes			Total Sales (logs)		
Human capital intensity	H1	H2	H3	H1	H2	H3	H1	H2	H3	H1	H2	H3
Dummy participation in FFC funds	2,12**	1,52	5,23***	-0,30	0,9***	0.67**	0.00	0.11*	0,18	0,06	0,12	0.37*
z	2,09	1,44	3.39	-0,86	2,87	2,33	0.00	1,66	1.58	0,68	0,82	1,84
Sector-Year Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Whitin R2	0.2248	0.2248	0.2248	0.1497	0.1497	0.1497	0.1810	0.1810	0.1810	0.1018	0.1018	0.1018
Between R2	0.0244	0.0244	0.0244	0.0000	0.0000	0.0000	0.0034	0.0034	0.0034	0.0067	0.0067	0.0067
Overall R2	0.1175	0.1175	0.1175	0.0451	0.0451	0.0451	0.1015	0.1015	0.1015	0.0000	0.0000	0.0000
Total Obs	6,274	6,274	6,274	6,443	6,443	6,443	6,021	6,021	6,021	5,961	5,961	5,961
# of Groups	734	734	734	734	734	734	673	673	673	673	673	673
Average obs per group	8,5	8,5	8,5	8,8	8,8	8,8	8,9	8,9	8,9	8,9	8,9	8,9

z: robust standard errors clustered at the firm level. *** significant at 1%;
** significant at 5%; * significant at 10%

Table 10 presents the regressions for the same variables as in the previous table but with the human capital intensity interaction indicator included. Firms with a larger share of university-level workers respond more strongly to government support for innovation expenditures and employment allocated to innovation activities. The same applies to self-reported outcomes, including improved or new products and total sales. Thus, as expected, the level of human capital plays a key role in influencing the innovation activities undertaken by firms and the impact of government support programs on various indicators of innovation inputs and outcomes.

Table 10. Heterogenous impacts by the proportion of university workers

Dependent Variable	Total Innovation Exp (logs)			Labor allocated to I+D+i (logs)			Products and Processes			Total Sales (logs)		
Age indicator	A1	A2	A3	A1	A2	A3	A1	A2	A3	A1	A2	A3
Dummy participation in FFC funds	2,63***	2,39***	3.42***	1,44***	-0,29	0,76***	0,08	0,02	0,16*	1,86***	-0,02	0,26**
z	3,45	2,61	2,72	6,68	-1,26	3.16	1,03	0.32	1,91	28,5	-0,14	2,06
Sector-Year Dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Whitin R2	0.2283	0.2283	0.2283	0.1483	0.1483	0.1483	0.1658	0.1658	0.1658	0.0931	0.0931	0.0931
Between R2	0.0196	0.0196	0.0196	0.0007	0.0007	0.0007	0.0042	0.0042	0.0042	0.0094	0.0094	0.0094
Overall R2	0.1193	0.1193	0.1193	0.0396	0.0396	0.0396	0.0843	0.0843	0.0843	0.0004	0.0004	0.0004
Total Obs	6,492	6,492	6,492	6,668	6,668	6,668	6,798	6,798	6,798	6,727	6,727	6,727
# of Groups	760	760	760	760	760	760	760	760	760	760	760	760
Average obs per group	8,5	8,5	8,5	8,8	8,8	8,8	8,9	8,9	8,9	8,9	8,9	8,9

z: robust standard errors clustered at the firm level. *** significant at 1%;
** significant at 5%; * significant at 10%

The estimation results for this sample of firms from the manufacturing sector in Argentina, where approximately 14% received public support for innovation activities, suggest that, in general, these policies have spurred innovation efforts[15]. This higher investment in innovation, partly stimulated by government policy, has helped launch new and improved products and production processes and expanded firms' employment and total sales. Some heterogeneous effects have also been identified: firms with a more educated labor force were able to take better opportunities for public support. Results by firm age are not clear-cut. Whether these government programs help promote the development of new innovative-prompted firms is an issue we will examine in detail in the next section. As we will suggest, public money is not enough for start-ups to flourish. A new kind of public-private collaboration is needed.

[15] In Sanguinetti and Feroce (2024), we show that this positive result could not avoid a partial crowd out of private innovation expenditures.

3. Grants to finance R&D in public research centers and universities: bridging the gap between sciences and business

Public money to promote R&D in universities and research centers is justified based on the significant knowledge spillovers that generate basic R&D. These externalities and spillovers together with limited access to financing by private actors -- due to the impossibility of using intangible assets as collateral or greater uncertainty about potential outcomes-, affect firms' incentives to engage in this activity. One key objective of these grants and funding is to generate new general knowledge that can be evaluated in terms of academic quality. Thus, public research grants usually (and understandably) aim to target the most promising researchers, projects, or socially significant problems.

However, public research and development grants may affect private firms in several ways beyond academic output. Universities or public research centers that receive these funds can generate spillovers to private firms, especially those near research facilities (Azoulay et al., 2019). In the case of the US, there is strong evidence of a correlation between areas with strong science-based universities and private-sector innovation (for example, Silicon Valley in California). Several papers have documented the significant impact of academic R&D on corporate patenting (Belenzon and Schankerman, 2013; Hausman, 2018). The transmission channels of these knowledge spillovers, identified in the literature, include direct personal interactions, formal collaboration agreements, university spin-off firms, consultancy, and the university's supply of a pool of highly trained graduates for employment in industry.

Most countries in Latin America, like Argentina, have established competitive research funds. Research excellence criteria guide the allocation of these resources. One issue that matters from the perspective of the impact on private incentives to innovate is to what extent some of these programs, beyond financing R&D in public institutions and universities, aim to generate positive spillovers regarding entrepreneurship and private firms' innovation efforts. We have already documented that this is the case in developed economies, such as the US. There is very scant evidence for Latin America and Argentina in particular.

3.1. The public scientific ecosystem in Argentina

To analyze the actual and potential spillovers of R&D public grants and other funding sources (such as year-long budget allocations) on entrepreneurship at public universities and research centers, it would be helpful to briefly describe the institutions that integrate the public scientific ecosystem in the country. Argentina has a long tradition of promoting basic research in the hard sciences, which has been well-recognized worldwide and is one of the best developed in Latin America. One key manifestation of this long-term policy is that it is the only country in the region to have won three Nobel Prizes in the hard sciences, including medicine and chemistry[16]. The leading institutions in this ecosystem are:

CONICET: The National Council for Scientific and Technical Research is the country's main research institution, with a similar structure to the French CNRS and the Italian CNRS. It was founded in 1958, and as of the end of 2023, it had a budget of $400 million USD and enrolled approximately 10,000 researchers (plus 11,000 doctoral and postdoctoral students). Approximately 75% of these researchers are dedicated to the hard sciences. CONICET coordinates investigations conducted both in its own research institutes

[16] This is the case of Bernardo Houssay (1947, Medicine), Luis Federico Leloir (1970, Chemistry), and César Milstein (1984, Medicine)

and at Universities (very often, the institutes have double affiliation with CONICET and a particular University, i.e., the Biological Research Institute with the National University of Mar del Plata). This collaboration also extends to teaching as many CONICET researchers are university professors.

Besides CONICET, there are two major government laboratories/innovation institutes: the National Institute for Agricultural Technology (INTA), and the National Institute for Industrial Technology (INTI), both founded in 1956. INTA is organized into a structure comprising a central headquarters, 15 regional centers, six research centers, 52 experimental stations, 22 research institutes, and over 400 technology extension units. Within the research institutes, it is worth mentioning the Ewald A. Favret Institute of Genetics (IGEAF), a functional unit of the National Institute of Agricultural Technology (INTA). It is part of the Center for Research in Veterinary and Agronomic Sciences (CICVyA).

Its function is to generate knowledge and develop strategic technologies through conducting fundamental and applied genetic research in plant, animal, and microorganism species that are important for the agricultural, agri-food, and agro-industrial sectors. INTA collaborates with private firms as well as with universities and non-profit organizations. Its funding comes from appropriations from the national government, competitive national and international funds (including US NIH and European Union funds), as well as contracts offered by private firms. INTI aims to support Argentine SMEs and promote industry development through innovation and technology transfer. It has numerous labs and technological centers across the country, covering several industry sectors, including food, textiles, biotechnology, oil and gas, automotive, agricultural machinery, and unique materials. It performs R&D and technology transfer activities.

A third critical factor in research and development associated with hard sciences is the system of public national universities[17]. Traditionally, they were created looking for geographical coverage across provincial jurisdictions and large cities nationwide. Still, in the last three decades, in part as a consequence of a rapid increase in demand for university education services, there was a surge of new national universities that now cover municipal territories; this was especially the case in the Great Buenos Aires area that concentrates a third of the country population (examples of this is the National University of San Martin, UNSAM, and the National University of Tres de Febrero, UNTREF, situated in the municipalities with the same name).

The development of this scientific ecosystem over the last 80 years has given Argentina a relatively significant position in terms of scientific capabilities, distinguishing it as one of the strongest in Latin America and with a close connection to leading world institutions. This is reflected in various indicators. For example, at the end of 2021, Argentina had over 60,000 researchers and doctoral students in the hard sciences, covering natural sciences, mathematics and physics, engineering and technology, medical sciences, and agronomic sciences (approximately 63% of all researchers and doctoral students)[18]. When measured per capita, Argentina has the highest number of researchers among the LATAM countries (Table 11).

[17] Most private universities have not developed research capacities in sciences.
[18] See Red de Indicadores de Ciencia y Tecnología (RICYT). https://www.ricyt.org/category/indicadores/

Table 11. Researcher per economically active population, 2012-2021.
Sample of LAC and developed countries.

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Argentina	4,67	4,74	4,80	4,72	4,89	4,70	4,82	4,80	5,16	4,88	4,82
Brazil	2,67	2,86	2,97	3,25	3,68	3,81	3,99	na	na	na	3,32
Chile	1,28	1,18	1,46	1,52	1,63	1,61	1,69	1,65	1,85	na	1,54
Colombia	0,00	0,34	0,34	0,41	0,53	0,52	0,66	0,68	0,85	0,91	0,52
Mexico	0,81	0,82	0,86	0,92	1,01	1,01	0,98	1,02	1,16	1,16	0,98
Perú	0,09	0,21	0,18	0,20	0,25	0,26	0,28	0,37	0,49	0,49	0,28
Latam	0,94	0,98	1,01	1,09	1,20	1,18	1,27	1,27	1,36	1,32	1,16
USA	7,95	8,13	8,29	8,30	8,13	8,36	8,93	8,99	9,95	na	8,56
Canada	8,58	8,18	8,60	8,89	8,58	8,54	9,15	9,43	9,97	na	8,88
Spain	5,41	5,31	5,33	5,34	5,55	5,86	6,14	6,25	6,40	6,64	5,82
Portugal	8,40	7,56	7,64	7,74	8,27	8,89	9,37	9,81	10,56	10,94	8,92

Sources: https://www.ricyt.org/category/indicadores/.

Another relevant input indicator is R&D expenditure. Overall, as of 2021, Argentina invests 0.52% of GDP (0.56% for the 2012-2021 average) in promoting science and technology activities, a level that is above that of other countries in the region such as Chile, Colombia, and Mexico but well below Brazil and some developed reference countries like the USA, Canada, Spain, and Portugal (Table 12).

Table 12. R&D expenditures as % of GDP. 2012-2021. Sample of LAC and developed countries.

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Argentina	0,63%	0,62%	0,59%	0,62%	0,56%	0,56%	0,49%	0,48%	0,54%	0,52%	0,56%
Brazil	1,13%	1,20%	1,27%	1,37%	1,29%	1,12%	1,19%	1,23%	1,17%	na	1,22%
Chile	0,36%	0,39%	0,38%	0,38%	0,37%	0,36%	0,37%	0,34%	0,34%	na	0,37%
Colombia	0,24%	0,27%	0,31%	0,37%	0,26%	0,24%	0,27%	0,21%	0,20%	0,20%	0,26%
Mexico	0,42%	0,43%	0,44%	0,43%	0,39%	0,33%	0,31%	0,28%	0,30%	0,28%	0,36%
Perú	0,06%	0,08%	0,11%	0,12%	0,12%	0,12%	0,13%	0,16%	0,17%	0,14%	0,12%
Latam	0,62%	0,65%	0,68%	0,70%	0,65%	0,61%	0,61%	0,61%	0,61%	0,61%	0,64%
USA	2,68%	2,71%	2,72%	2,78%	2,85%	2,91%	3,01%	3,17%	3,42%	na	2,92%
Canada	1,77%	1,71%	1,71%	1,69%	1,73%	1,69%	1,74%	0,18%	1,89%	1,70%	1,58%
Spain	1,30%	1,28%	1,24%	1,22%	1,19%	1,21%	1,24%	1,25%	1,41%	1,43%	1,28%
Portugal	1,38%	1,32%	1,29%	1,24%	1,28%	1,32%	1,35%	1,40%	1,61%	1,68%	1,39%

Sources: https://www.ricyt.org/category/indicadores/

The vast majority of these R&D expenditures, 80%, are made by the public sector through money allocated to public research centers and universities (78% goes to hard sciences) and the subsidies that promote innovation in private firms, as mentioned in the previous section. Though the available information is scarce, preliminary estimations suggest that this last item represents a tiny proportion of all R&D expenditures (less than 5%).

One traditional output indicator of R&D activities is the number of publications. The latest data in Scopus (Table 13) shows that Argentina had around 39,3 per thousand inhabitants (covering all science topics, including social and humanity), which is higher compared to the (weighted) average of LAC. However, it is well below developed economies and some other Latin American countries like Brazil and Chile (though higher than Mexico and Colombia).

Table 13. Number of publications in Scopus, 2013-2021 (per 100000 individuals).
Sample of LAC and developed countries.

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Argentina	29,8	31,6	32,0	32,7	33,3	35,0	35,1	39,3	39,4	34,2
Brazil	32,4	33,9	35,2	37,1	39,1	41,4	43,3	46,2	48,4	39,7
Chile	53,3	62,2	66,2	74,7	75,5	82,3	86,7	97,3	104,8	78,1
Colombia	16,2	17,8	19,5	22,4	24,7	28,1	31,3	34,0	35,6	25,5
México	16,7	17,7	18,0	19,1	20,2	21,4	23,3	24,8	26,3	20,8
Perú	5,4	6,0	7,2	8,3	9,8	11,4	15,0	20,2	24,5	12,0
LAC	19,9	21,1	21,8	23,2	24,5	26,1	27,8	30,1	31,5	25,1
USA	218,1	214,0	218,9	219,7	223,7	225,9	222,5	220,3	228,3	221,2
Canada	286,7	294,1	295,6	300,6	312,9	318,0	321,6	328,6	347,8	311,8
Spain	187,4	194,4	196,8	203,0	208,5	214,7	226,3	246,2	264,7	215,8
Portugal	220,1	226,8	241,6	249,4	257,7	270,9	299,2	322,5	355,4	271,5

Sources: https://www.ricyt.org/category/indicadores/

Finally, an innovation indicator that is closely examined is the number of patents. Although many patents registered often do not result in new goods and services sold in the market, they serve as an indirect measure of R&D output that could eventually have some economic value. Table 14 shows the number of patents submitted for approval by residents in each country, per 1,000 population. To gauge the innovation effort and its outcomes within each country, the right indicator is the number of patents developed by local researchers and inventors[19]. Except for Brazil, the rest of the LAC countries considered in the analysis have residence patenting activity indicators that are significantly lower than those of developed economies. Argentina is above Colombia and Mexico, but far below Brazil, which is slightly above Spain.

Table 14. Patent Submissions by Residents per 100,000 population, 2013-2021.
Sample of LAC and developed countries.

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	Mean
Argentina	1,52	1,19	1,20	1,96	0,89	0,92	0,99	2,18	0,89	1,31
Brazil	3,99	3,67	3,64	3,96	4,07	3,64	3,96	3,77	3,42	3,79
Chile	1,93	2,53	2,46	2,11	2,27	2,15	2,31	1,91	2,03	2,19
Colombia	0,51	0,54	0,66	1,04	1,13	0,84	0,85	0,73	na	0,79
Mexico	1,01	1,03	1,11	1,06	1,07	1,23	1,03	0,88	0,87	1,03
Perú	0,24	0,28	0,22	0,22	0,33	0,28	0,42	0,38	0,29	0,29
LAC	1,80	1,70	1,69	1,88	1,85	1,73	1,77	1,75	1,53	1,75
Canadaá	12,97	11,81	11,94	11,25	11,26	13,53	13,36	14,46	12,38	12,55
España	6,34	6,20	5,92	5,82	4,62	3,18	2,69	2,96	2,72	4,49
USA	91,02	89,48	89,82	91,34	90,40	87,23	86,84	na	78,98	88,14
Portugal	6,19	6,95	8,92	7,00	6,23	6,40	6,78	6,69	6,82	6,89

Sources: https://www.ricyt.org/category/indicadores/

3.2 Technological transfer initiatives and university incubators/spin-offs

Investment in basic research does not automatically translate into the development of new technologies and their adoption by private actors. Promoting and improving the links and coordination between the scientific system and companies is necessary. From a public sector perspective, it involves effective

[19]The non-resident application of patents is mainly associated with R&D carried out in foreign countries.

mechanisms for linking science with commercial applications, which entails the creation of new firms and/or transferring applied knowledge to existing enterprises. For this reason, it is crucial to determine whether the scientific ecosystem has implemented technological transfer or collaboration proposals with firms and/or schemes to promote start-ups through incubators or university spin-offs.

Establishing initiatives to foster commercial applications of scientific ideas and technologies developed by public universities and labs is a relatively new activity in Argentina, and as we will see, it is still a developing process. One of the first initiatives was established in the largest and most research-active university, the National University of Buenos Aires (UBA), which has a technology incubator called INCUBACEN, based on technologies developed at the Faculty of Natural Sciences[20]. One of the keys that has made these types of activities possible has been the realization of a gradual cultural change within the scientific and technological system, in which an increasing number of its members accept to work on applied projects articulated with the productive sector[21].

Within UBA, the Agronomics Faculty launched another incubator, INCUBAGRO, in 2010 to promote start-ups and productive initiatives linked to agriculture. Since its foundation, it has incubated eight start-ups, among which Grupo IFES (Innovations for a Sustainable Energy Future), a renewable energy company that recently, and for the first time in Argentina, exported a biogas plant to Costa Rica[22].

One interesting case of an initiative to bridge the gap between science and businesses from a public sector actor agency is that of the incubator IDEAR (Incubadora de Empresas de Ambito Regional) created in 2002 between the Universidad del Litoral and the Municipality of Esperanza in the province of Santa Fe. IDEAR was born to create competitive companies and strengthen the socio-productive fabric of the region. This incubation system incorporates education, science, and technological development into enterprises and companies, which are fundamental elements for generating wealth. Currently, there are 15 start-ups in the incubator process, while around 15 more have graduated[23].

The Universidad Nacional de La Plata (UNLP) has established MINERVA, an incubator created in 2014 within the structure of this educational institution (it formally depends on the secretary of technological transfer/connection with private sector actors). Its main objective is to support entrepreneurial development in the university community and promote the link with the entrepreneurial ecosystem. Minerva promotes the creation and development of technology-based companies, highlighting the scientific knowledge generated in laboratories and university centers. As of December 2024, it has incubated around five firms, among which it is worth mentioning Logia Biotech, the first science-based enterprise (SBE) created in UNLP. Logia Biotech is dedicated to developing an innovative system for detecting antigens or viral components to diagnose respiratory diseases[24].

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[20] This incubator was created in 2003. Within the firms that were incubated, it is worth mentioning NEOINOCS, which developed microbial inoculants for plants. Another one, Biocodices, is working on bio-informatics. A third one, POLICLON, is developing biological reagents for animal health. Overall, as of 2013, after 10 years, nine companies were created. Still, the last call for projects was launched in 2014. No activity is reported after that year. See https://incubacen.exactas.uba.ar/?page_id=997

[21] In an interview in 2014, Ezequiel Litichever, General Coordinator of INCUBACEN, mentioned, "This transformation in values has been very significant. Today, we see it in the number of researchers, graduates, and students who come to the incubator. Although some still oppose it, the consensus reached is very broad". https://incubacen.exactas.uba.ar/?p=2779

[22] See https://noticias.agro.uba.ar/actualidad-news/empresa-incubada-en-fauba-exporta-tecnologia-sustentable-centroamerica

[23] See https://www.unl.edu.ar/vinculacion/incubadoras/

[24] See https://www.minerva.unlp.edu.ar/

Another university that has recently become very active in entrepreneurial activity is Universidad de San Martin (located in the Metropolitan Area of Buenos Aires). Associated with the Biotechnological Research Institute (IIB-INTECH), it has an incubator that links science generated at its facilities with entrepreneurial activities and start-ups. Given the type of research done in that research institute, it specializes in promoting biotechnological firms. Within their mandate, they have the mission of …" transferring biotechnological findings from the laboratory to the productive sector. Our job is to motivate, support, and train our researchers to create startups…"[25]

Various other public universities have recently joined these initiatives to establish incubators, promoting the creation of science and technology-based start-ups and enterprises from the knowledge and innovation generated within their institutions. To exchange experiences and information, the Network of University Spinn-Offs (Red SOU) was established in 2024, founded by the University of La Plata, Universidad del Litoral, and Universidad de San Martin. Other Universities associated with this initiative are the Universidad Nacional de Cuyo, Universidad Nacional de Córdoba, and Universidad Nacional de Tucumán.

The initiatives described above aim to counteract various factors that limit the potential for research conducted at these institutions to have positive spillovers, promoting start-ups and enterprises that can increase the economy's productivity. Besides the already mentioned issues associated with cultural factors that make researchers uncomfortable when looking at the business implications of their investigation, in Argentina, as well as in other countries, the priorities of the local scientific sector are not primarily oriented toward the production of innovations with defined commercial use (Anlló et al., 2016; Romani et al., 2016). The incentives of evaluation systems for research professionals are generally aimed at producing better publications in peer-reviewed journals, which hinders the possibilities of public-private linkage (Romani et al., 2016; Orbita, 2020)[26]. However, as we will explain in more detail below, even if a researcher is in favor of transforming an invention into a business venture, they would face restrictions on becoming part of a private business initiative. Some of these restrictions are associated with regulations regarding patent ownership and technology licensing procedures, as well as constraints for obtaining an appointment as founder or CEO of a private firm.

In addition, the views gathered through various interviews with key actors in the entrepreneurship ecosystem suggest that some of the technology transfer offices and/or spin-off organizations created within the public research institutions often lack the necessary skills to perform their jobs, specifically a

[25] https://noticias.unsam.edu.ar/2016/11/15/un-jurado-internacional-destaco-la-incubadora-del-iib-intech/

[26] For some authors, there is tension when promoting policies that try to link science with business. Although public-private linkage is desirable for creating start-ups and economic value out of scientific discoveries, intensifying these linkages generates a series of risks for the local scientific-technological system. Technology transfer activities entail two types of potential risks for the public production of scientific and technological knowledge: "privatization risk" and "opportunity cost increase risk" (Arza and Carattoli, 2012). The first refers to the possibility that the results of public efforts are appropriated privately by companies and that the research agendas of public institutions are co-opted exclusively by the interests of the private sector, neglecting areas of greater interest to society. The second refers to the trade-off between the time a researcher spends liaising with the private sector and the time spent on basic research, teaching activities, or human resources training (Arza & Carattoli, 2012). It is unclear whether the "private appropriation" argument is well founded when considering aggregate social welfare. Commercializing a research product (say, a vaccine), which cannot be implemented sustainably without a business model that allocates resources to production and distribution and partly finances these costs by market sales (there always can be a partial no-profit appropriation of these products), can save millions of lives. As for the trade-off between research time and business management duties, this may be significantly reduced when there is a collaboration between scientists and entrepreneurs. We discuss this collaboration below.

lack of business or financial training. Moreover, when they do have these skills, they are subject to institutional and procedural tasks that limit their effectiveness (O´Farrel, 2022)[27].

We may think that these low incentives on the part of the researchers and the failure of some specific institutional organizations within the public sector research organizations (like spinn-off offices/incubators/technology transfer appointees, etc.) to bridge the gap with the business community could be replaced by the action of science-oriented entrepreneurs, who, though they lack the specific scientific knowledge embedded in particular inventions, could help to develop a business idea and commercial applications of these discoveries. However, then the problem is the lack of an up-to-date database of public access that centralizes the information on the various scientific projects (with adequate detail of the degree of progress) of the different bodies and institutions of the local scientific system, which hinders the effort of the private sector and potential entrepreneurs to identify potential business opportunities coming from scientific discoveries in various fields.

As we will develop below, some of these problems have been in part addressed by some new private sector actors, constituted by a new wave of incubators/accelerators/venture capital institutions that have taken the task of reaching out to the scientific community looking for research and scientific discoveries that can be turned into a business with a global impact. We will describe this next.

3.3. The role of new private sector-run incubators/accelerators: the case of the biotechnology industry

To illustrate how a new type of institutional collaboration between academia and business interests has bridged the gap between science and entrepreneurship, we will take the biotechnology sector as a case study. The selection of this activity should come as no surprise. Many examples we have already given of spin-offs and start-ups incubated in public universities or public research centers belong to this sector. This is partly associated with the country's significant role in global agricultural production, livestock, and food—also, the growing importance of its pharmaceutical industry in domestic and regional markets.

Global trends in the biotechnology industry

Let us start by defining what we mean by biotechnology products and services. According to the OECD (2009), biotechnology is the application of science and engineering to the direct or indirect use of living organisms or their parts, in their natural or modified forms, in an innovative way for the production of goods and services or for the improvement of existing industrial processes. It encompasses several modern biotechnology tools, including rDNA technologies, genetics, biochemistry, immunochemistry, and chemical engineering, among other bioprocessing technologies. From this definition, it is clear that it is challenging to encapsulate biotechnology as a specific productive sector; it is not an industry but a set of general-purpose technologies applied to many industries, such as agriculture, environmental remediation services, food, mining, pharmaceuticals, and other industrial activities (OECD, 2009).

[27] One example of these difficulties is INCUINTA, an incubator or technology transfer mechanism established with INTA. Its function is to interface research and production on an industrial scale. To this end, it must evaluate and select the research with the most significant potential to contribute to national technological development, analyze the needs of the productive sector, implement developments arising from research on a pilot scale, and assess their technical feasibility, economic profitability, and regulatory implications. Though INTA has an excellent reputation for addressing technological challenges faced by agriculture producers, its task as an incubator of newly created firms out of scientific discoveries made in their labs has been challenged by the lack of skills to perform all the above-mentioned duties (O´Farrel, 2022).

Biotechnology as a science was born in the United Kingdom and the United States (USA). However, its commercial applications were first developed in the United States in the mid-1970s (Niosi and Bas, 2013). In the following years, thousands of dedicated biotechnology firms were established in the United States, Western Europe, Canada, Japan, and other regions. In OECD countries, they were funded by government subsidies and venture capital afterward. Most of the products and services invented by these companies require significant funding and skills to be developed. Dedicated biotechnology firms (DBF) specialized in human health products allied with large pharmaceutical corporations to obtain approval and market them. DBF specialized in new seeds and often gave licenses to large grain traders such as Monsanto and Syngenta.

In recent years, the underlying science base of biotechnology has had major breakthroughs, which have opened new commercial opportunities for small and medium-sized enterprises (Niosi and Bas, 2013). Thus, in 2003, human genome sequencing enabled the creation of a new field of biotechnology known as genomics. Using this information and technology, small and medium-sized DBF could offer gene-sequencing services to pharmaceutical corporations, farms, governments, and individuals. In addition, since 2013, a new gene-editing technology called CRISPR has been developed with many biotechnological applications, such as in agriculture and pharma. At the same time, the new developments in digital technologies, such as cloud computing, machine learning, and artificial intelligence, combined with the vast number of documents produced by biotechnology research (including millions of patents, scientific publications, and approval applications), have supported the growth of bioinformatics. This service industry retrieves, stores, and analyses the millions of genetic information stemming from increasingly powerful and rapid sequencing equipment[28]. Bioinformatics also analyzes information about the collateral effects of drugs, which can rapidly lead to the discovery of new medicines (Niosi and Bas, 2013). In the case of agriculture and animal health, large microbiome data sets facilitate the development of novel solutions that can enhance nutrition and health for plants and animals. The rise of sophisticated and extensive computer modeling using AI and insights from genetics and microbiomes can supplement traditionally slow, sequential experimentation and open the door for these new platforms to compete. All these new developments have reduced the cost of developing biotechnology products and services, allowing small, science-based start-ups currently at the forefront of innovation to enter the market (Chui et al., 2020).

The United States remains the leader in scientific publication and commercial application of biotechnology. Australia, Canada, Israel, Europe, and Japan strive to catch up with the leader. Some emerging countries in Africa, Asia, and Latin America are also entering into the race. They include Argentina, Brazil, China, India, Mexico, Singapore, South Africa, and South Korea. Their publication patterns show that their scientific base is catching up. However, they lack adequate complementary institutions, such as public and private venture capital organizations and public policy incentives, to allow them to catch up in commercial biotechnology (Noise et al., 2012). We comment below on the specific case of Argentina.

The biotechnology industry in Argentina

[28] This is the case, for example, of Phylumtech, an Argentine biotech company founded in 2009 whose primary focus is the creation of effective technologies for discovering new drugs and molecules *in vivo* models combining biotechnology, automation, software, and bioinformatics. See https://www.phylumtech.com/home/es/empresa/

Argentina had a leading start in biotechnology in the region. In the early 1980s, it had a prompt entry in science, with Dr Cesar Milstein, future Nobel Prize winner and discoverer of the methods to produce monoclonal antibodies. Argentina also strongly demanded genetically modified organisms (GMOs) from its large agricultural sector and biopharmaceutical drugs produced by a large generic pharmaceutical industry (Harr, 2017). In 1983, the first local private initiative in this field occurred with the development of a recombinant protein by Biosidus, which subsequently became the first Argentine biotechnology company. Since then, the private biotechnology sector in Argentina has demonstrated signs of growth, as evidenced by increases in the number of companies, sales, exports, and research and development (R&D) efforts, as shown below.

However, this growth of the productive fabric occurred alongside significant changes in the structure of business activity (Stubrin, 2022). At the beginning, in the 1980s, non-DB firms predominated. These were companies with technological and productive capabilities in related areas of knowledge (biology, chemistry, or agronomy) that diversified into biotechnology. However, over the following two decades, the growth of the biotechnology business network is primarily attributed to the emergence of DB firms, which gained a significant presence in the composition of the productive network across various application areas, including human health, animal health, agriculture, and industrial processing.

One notable success from this period was the establishment of Bioceres in 2001. It was founded by a group of farmers from Rosario in the province of Santa Fe. These farmers/entrepreneurs were aware of the broad capacities of the Argentine scientific and technical system. They noted the difficulty in transforming that knowledge into innovations that impact production. They set themselves the goal of creating a company that would collaborate with the scientific sector to generate biotechnological innovations serving the agricultural sector's needs. Over time, Bioseres evolved into a company that provided technological services and R&D focused on biotechnology[29]. For example, the firm has been a key partner in developing the patent for the HB4, a seed resistant to drought, in collaboration with Dr. Chen and his team at the Universidad del Litoral. It was the first Latin American biotechnological firm whose securities were traded on the NASDAQ.

In more recent years, from the mid-2010s onwards, and following the global trends described above, a new type of firm, start-ups, has predominantly driven the growth in the sector's business base (Stubrin, 2022). As we will demonstrate below, this was partly a consequence of the efforts to establish technology transfer and spin-off initiatives in public universities and research centers. However, even more critical was the surge of new private sector-run incubators, accelerators, and venture capital organizations.

A difficulty in measuring the weight of the biotechnology sector within the economy is that, as it is a set of techniques applied to numerous activities, it is impossible to rely on traditional sectoral data sources. To address this issue in 2023, the National Innovation Agency, in collaboration with other institutions,[30] conducted a survey of biotechnological enterprises (Stubrin et al., 2024). Using the OECD methodology, firms included in the census were those with the capacity to utilize biotechnological technologies in R&D activities, producing goods and/or providing services. According to the survey, there were 340 firms

[29] To this end, it partnered with CONICET to establish the “Instituto de Agrobiotecnología de Rosario” (INDEAR) in 2004, eventually becoming the firm's R&D center.

[30] Other participants were the Argentine Chamber of Biotechnology (CAB), the Argentine Nanotechnology Foundation (FAN), the Federal Investment Council (CFI), and the Center for Research for Transformation (CENIT) of the School of Economics and Business of the National University of San Martín (EEyN—UNSAM). The Biotechnology Cluster of Córdoba and the Bio Cluster of the Province of Santa Fe also supported it.

developing biotechnology activities in Argentina in 2023[31]. Although still well below leading countries in this industry, which have around a thousand or more companies (such as the United States, France, Canada, Spain, Korea, Italy, and Germany), the country leads Latin America in the number of firms[32].

Using previous censuses employing the same methodology, it can be concluded that in the last 15 years, biotechnology companies have almost tripled in Argentina, from 120 firms in 2008 to 340 in 2023 (Stubrin et al., 2024). As we will show below, this significant growth in the number of firms is explained by the surge of start-ups (firms aged 7 years or less).

As is the case in other countries, there is a high geographic concentration in the localization of these firms. 90% of Argentine biotechnology companies are concentrated in four geographical districts: the City of Buenos Aires (90 companies, 26%), the province of Buenos Aires (87 companies, 25%), Santa Fe (77 companies, 23%) and Córdoba (52 companies, 15%). As we will see, this concentration is a consequence of regional patterns in the localization of scientific and entrepreneurial capacities in this field.

Table 15 summarizes other indicators from the biotechnology sector survey covering 210 firms interviewed in 2023. The first thing to notice is that most firms are start-ups (see below) with 10 or fewer employees (53%). Only 11% (around 24 firms) are large established enterprises with over 250 workers. Most of these workers are highly educated, as 27% have completed undergraduate studies, while 6% and 5% have achieved Masters and Ph.D. degrees, respectively. This level of education is much higher than that observed for the manufacturing sector, where, as has been shown before (see Table 1), only 8.5% of the labor force has university studies[33]. Altogether, these firms generated sales for a little bit less than 4 billion dollars in 2022. Exports were around 700 million USD, representing 19% of total sales. This export ratio is more than double that found for the manufacturing sector in Argentina. Also, R%D expenditure intensity is 3.38, almost doubling the one shown in the previous section for the sample of manufacturing firms used in the estimation of section 2 (close to 1,8%). Thus, as expected, the biotechnology sector comprises very innovative, highly educated, export-oriented firms[34].

Table 15. performance indicators of biotechnology firms. Year 2022.

Size		Education		Other performance indicators		Firms origin		
Micro (-10)	53%	Non university	62%	# employees	20000	2010-19	University Spin-off	11 (18,6%)
Small (10-50)	26%	Undergraduate	27%	Sales (millions USD)	3752	(59 firms)	Company builders	9 (15,2%)
Medium (50-250)	9,5%	Maters	6%	Exports (millions USD)	708	2020-23	University Spin-off	16 (19,5%)
Large (+250)	11%	Ph.D	5%	R& Expenditures/sales	3,38%	(82 firms)	Company builders	26 (31,7%)

Source: own elaboration using data from Stubrin et al. 2024.

A last issue that is interesting to analyze is the origin of these biotechnology firms and to what extent University spin-offs and privately run incubators/accelerators played an important role. The survey allows a precise answer to this issue. As shown in Table 15 (fourth column), between 2010 and 2019, among the 59 firms that were created, these two mechanisms explain around 34% of the newly created

[31] This number comes from the 210 firms that actually participated in the survey, plus secondary sources such as information obtained from the Argentine Chamber of Biotechnology.

[32] We must be cautious about this comparison as other countries have not updated their data on the number of biotechnology firms as shown in the OECD (2019) repository.

[33] For the case of firms that were created after 2015, the education indicator is much higher as 73 have completed undergraduate studies, and within them, many of them have Master's and Ph.D. degrees (Stubrin et al. 2024)

[34] As emphasized in the previous discussion, a key factor that has improved the productivity of new start-up firms in the biotechnology sector is the application of bioinformatics. The survey applied to biotechnology firms in Argentina shows that close to 60% of the start-ups born after 2015 employ these technologies for R&D or in their productive processes, while this was less than 22% for the firms created before 2015.

biotechnology enterprises (11 firms were born out of University Spinn-off while 9 were the results of company builders/accelerators). This trend has changed significantly in recent years. Between 2020-2023 out of the 82 new firms (note the acceleration of the firm's creation process), more than 50% were born using these two instruments. Among them, accelerator company builders have been the main force (26 against 16 enterprises coming from university spin-offs). We analyze the role of these institutions next.

The new actor: company builders and accelerators

The surge of new company builders and accelerators run by private sector interests, in many cases in collaboration with or associated with public universities and research centers, comes as a way to address some of the problems we have already mentioned regarding the existing initiatives of public research institutions in establishing technology transfer offices to contact and collaborate with private enterprises. We summarize them in the following four items: (i) lack of institutional incentives for researchers, which restrains them from allocating more time and resources to technology transfer activities and cooperation with the private sector; (ii) a significant lack of knowledge on the part of the private sector of the R&D capacities in biotechnology in the public science and technology sector. (iii) bureaucratic processes in the public system that can be very long, which delay and hinder the transfer of knowledge and networking with the private sector; (iv) low and discontinuity of public funds support for new scientific-based private ventures.

Below, we will describe three cases of accelerators/VC organizations that have partially overcome these limitations. These are CITES, GRIDEX, and SF-500[35]. These institutions have conducted scouting activities to reach out to the scientific community to identify economically viable projects with global impact; they bring entrepreneurial capacities to the scientific founders, which could help with business strategy and day-to-day management of the start-up (so scientific founders do not need to take too much time out from their investigations); they offer these new ventures seed funds and the possibility to access to venture capital funds; and helped science-based start-ups with bureaucratic and regulation issues.

CITES: Center for Technological, Business and Social Innovation was created in 2013 in Sunchales, province of Santa Fe. It is the first scientific accelerator/venture capital organization in the country. Their primary focus is supporting the development of scientific and technological startups driven by revolutionary ideas that address significant modern challenges. It has incubated firms specializing in biotechnology products and services and other scientific fields like IA and medical devices. Their main activities/services are: (i) Investment: CITES provides financial support to startups, offering up to USD 750,000 in seed funding and up to USD 600,000 in follow-on investments. (ii) Active Management: They offer hands-on management assistance, with their team available to guide startups through various stages of entrepreneurship development. (iii) Connections: CITES facilitates access to global networks of mentors, strategic partners, experts, entrepreneurs, and investors, fostering collaboration and growth opportunities; (iv) Infrastructure: they provide state-of-the-art facilities, including fab-labs, wet-labs, spin-off labs, co-working spaces, and private offices located in Sunchales, Buenos Aires (CABA), and Bariloche. Since the year of its foundation, it has evaluated 2300 projects, mentored around 170 start-ups, and provided seed capital or follow-on investment for 18 firms, 9 of which have received investment from third partners.

[35] For reasons of space, we have left out *Aceleradora del Litoral*, another relevant case of a new privately run incubator, accelerator, and VC organization that has been very active in promoting the development of start-ups in the biotechnology sector.

Also, one firm has reached a partial cash "out stage."[36] Interestingly, 83% of the personnel involved in all these firms are researchers (43% of foreign origin) and have licensed 60 patents from the scientific ecosystem (CONICET and Universities)[37].

GRIDX (GRID Exponential): Created in 2017, it defines itself as a company builder focused on biotechnology. It links scientists from the academic field with business entrepreneurs. To this end, one of GridX's first tasks is to map research with potential in universities, laboratories, and research institutes throughout the country. As of the end of 2023, GRIDEX has identified more than 1500 research projects within the Argentine scientific ecosystem that could become business ventures with global impact (GRIDEX, 2024)[38][39]. The criteria for considering a project mappable are: (i) original and potentially competitive science; (ii) that this science can solve a current or future problem of the market; (iii) and finally, the intention of the scientific group in wanting to go through the process of transforming its academic scientific project into a scientifically based business project.

At the same time, GRIDX is looking for young entrepreneurs interested in formulating business projects to bring these scientific ideas or discoveries to the market. Thus, a match is made between scientists and entrepreneurs, each bringing their specialized expertise to the project. The selection process begins with an initial universe of 100 projects per year, of which 20 are chosen to participate in an immersion program (three-month workshop) in the startup world. Thus, GridX builds companies by assembling teams, uniting scientists with entrepreneurs, and investing up to $200,000 per project in seed capital. The objective is to create 200 companies in 10 years. As of the end of 2024, GRIDEX has the most extensive portfolio of bio start-ups within the country and Latin America, as it has invested seed capital in 50 companies in Argentina and 28 others distributed in various other Latin American countries. This has been possible through developing its own VC/investment fund with the support of leading Argentine biotechnology companies such as Insud, Bagó, Gador, Bioceres, Vicentin, y Sinergium Biotech.

SF500: it was founded in 2021 by an alliance between the government of the province of Santa Fe and Bioceress. Its mission is to promote the creation of biotechnological-oriented start-ups that transform scientific advancements into actionable solutions that address critical global challenges. For this objective, it aims to create 500 companies during a period of 10 years, offering both mentoring/entrepreneurship training and investment funds. As in the case of GRIDEX, one initial task that SF-500 performed was reaching out to scientists in different universities and research institutes in the country to evaluate research projects and produce an inventory of potential research outputs with potential commercial and global applications[40].

The process of company building in SF-500 takes three steps: (i) The organization operates SFBuild, a three-month program for selected 15 projects in which teams of scientists and entrepreneurs are trained and mentored for launching a biotech startup. The free program is conducted primarily online, with two in-person meetings in Rosario and another selected city in Argentina[41]. This program aims to produce a

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[36] This means that CITES has partially sold its equity or ownership in the startup.

[37] CITES, Reporte ASG (Ambiental, Social y de Gobernanza), 2024.

[38] For this task, GRIDEX contacted and evaluated research projects in 108 institutions nationwide, representing about 44% of the total number of research centers associated with life sciences.

[39] In an interview performed for this study, Matias Peire, CEO of GRIDEX, has updated this number to 4500 research initiatives that the team at GRIDEX has mapped, now expanding the sample to other countries in Latin America.

[40] The information we gathered from the interviews with SF-500 officials suggests that this was a very time-consuming activity (many trips around the country were made to meet around 1300 researchers). However, it was relevant to make the initiative known to the scientific community and assess the potential projects the scheme can support.

[41] Participants receive online formation: sessions with founders and industry specialists, 1-on-1 training with mentors and workshops.

match between scientists and business entrepreneurs, who ideally will become co-founders of the start-ups. (ii) Once the training program is completed, startups approved by the Investment Committee will receive a US$250k as a pre-seed investment. (iii) New seed capital rounds can be allocated after the first pre-seed investment. In this process, the start-up receives advice on fundraising strategy, connections with other funds, and partnerships.

To perform its investment services as a venture capital firm, SF-500 manages a 30 USD million fund, which was constituted by capital allocation by Bioseres and the government of Santa Fe. The fund is legally constituted as a private financial trust that has a trustee with an institutional profile. As of November 2024, SF500 invested $8,6 million in 24 biotech start-ups covering areas like human health, bio inputs/enzymes for industrial applications, biofertilizers, and other applications for sustainable agriculture, among others, which have implied the development of 32 patents.

Table 16 summarizes some other features of these incubator/accelerator/VC organizations. As we mentioned before, these institutions try to cover all the stages in the financing cycle of the firms: pre-seed, seed, follow-on, and venture capital investment. One important feature that should also be mentioned is that in exchange for all the services – training, mentoring, infrastructure, evaluation, consulting, financing- that these institutions provide to scientists and entrepreneurs, they keep of share of the equity of the firm to be cashable later when the start-up has already a consolidated position in the market. This share is 45% in the case of CITES and about 25% for GRIDX and SF-500. Also interesting is that most of them received public funds at an initial stage, which helped them start their operation. In the case of GRIDEX and CITES from the FONDCE national fund, while SF-500 has received some funding from the Province of Santa Fe. We discuss the role of public funds in promoting these intermediate institutions in the next section.

Table 16. Some features of Accelerations/VC institutions

Variables	CITES	GRIDX	SF500
Start-up stage financing services	seed/follow-on/VC	seed/follow-on/VC	seed/follow-on/VC
Ticket pre-seed and seed	USD 500 mil	USD 200 mil	USD 250 mil
Follow-on rounds	USD 600 mil	USD 1 MM	USD 500 mil
Equity	45%	20-25%	25%
Countries covered	Regional	Regional	Regional
Own labs	YES	NO	NO
Employment	10	11	13
Founding Institution	Sancor Seguros		Bioceres/Sta Fe Gov
Vertical	Deeptech	Bio	Life sciences
Number of start-ups invested (as of dec 202	18	78	24
Year of first investment	2016	2017	2022
Start-ups in commercial stage (as of dec 202	3 (37% of the portfolio)	11 (20% of the portfolio)	No data
Employmnent generated by the invested sta	82	650	No data
Employment in Argentina	34 (41% del total)	520 (80% del total)	63 (92% del total)
Share of start-ups using labs in Argentina	75%	100%	100%
VC funds coming fron foreign sources	USD 10M	43% of the portfolio	7.7% of the portfolio
Access to funds from FONDCE	yes	Yes	No
Objective regarding # of invested start-ups	32 in 5 years	200 in 10 years	500 in 10 years

Source: Gonzalo et al., 2023 and web pages.

One final interesting issue concerning the consequence of the establishment of these accelerators/VC institutions is that some of them, like the case of SF 500, are part of regional scientific and entrepreneurship ecosystems, which have promoted the development of subnational territories with the creation of start-ups and firms that helped to increase the productivity and diversification of local economies. The case of the cities of Santa Fe and Rosario within the province of Santa Fe is a paradigmatic case that has received much attention from policymakers and social researchers alike (see Bortz et al., 2023; Bercovich and Bortz, 2024; O'Farrell et al., 2023). However, there were other engaging experiences in Cordoba and Medoza (Brizuela et al., 2022).

3.4 Lessons and policy challenges for promoting science-based private ventures

The discussion in the previous sections suggests that Argentina has had noteworthy experiences with initiatives to promote science-based start-ups supported by intangible capital derived from scientific ideas and discoveries with global impact. What lessons and policy challenges lie ahead for further promoting these science-based, highly innovative private ventures? We discuss this below.

Scientific capabilities and public budget restrictions

Over the last 75 years, Argentina has made significant efforts to establish a robust scientific system that has distinguished itself both regionally and globally. The creation of CONICET, public universities, and public research centers like INTA and INTI, has been a key determinant for having a scientific ecosystem that shows a very high density per thousand of the economically active population and relatively good quality according to some indicators (the Scimago ranking puts CONICET in 141st place out of 8,000 scientific institutions in the world (GRIDEX 2017)). In addition, its broad territorial coverage has helped to partly focus its research on issues affecting the social and economic development of the various regions, which in turn, in some cases, have helped to spur the creation of knowledge/production clusters (as was the case of the Province of Santa Fe referred to above).

Of course, when we discuss public money financing science for a country like Argentina, there is the issue of how the numerous recurrent macroeconomic crises that have affected the country have influenced the allocation of real resources to this activity and its impact on the long-term trend of building scientific capabilities. The overall expenditure in R&D has been around 5000 million PPP USD since 2012 but with significant declines in years of inflationary and macroeconomic crises (i.e., 2019) or fiscal adjustment measures (i.e., 2016, 2018, 2024). In terms of GDP, an evident decline is observed, as R&D expenditure was approximately 0.63% of national wealth in 2012 and decreased to 0.52% in 2021 (refer to Table 12). Abrupt changes in financing science could disrupt long-standing planned research projects[42]. If this volatility persists and budget cuts affect the wages and salaries of key investigators more permanently, it could significantly impact human capital capabilities, as researchers may emigrate (or even deter the entry of bright individuals into science).

Beyond the necessary revision of budget priorities that need to be addressed[43], there are alternative ways that Universities and Research Centers could partly finance their activities by charging fees for the R&D and technology transfer services they offer to private parties. This is done in some institutions (such as INTA), but the collected resources are often used for purposes other than paying honorary fees to the

[42] Recurrent budget instability and inflation have affected the effectiveness of specific R&D promotion policies. For example, in the case of the FONARSEC program, budget restrictions led to significant volatility in the amount of funds allocated and disbursed (Kantis, 2016).

[43] For example, the 2017 Law of Entrepreneurship set the objective to increase R&D spending to 1% of GDP by 2027.

involved researchers[44]. Also, licensing patents developed through the public scientific ecosystem could be a source of funds. Still, as we explained below, these sources of funds are difficult to value and set the corresponding fees given the high uncertainty of market applications and commercial development during the first stages of the start-ups.

In other cases, public research centers like INTA have obtained financial resources by appropriating revenues associated with distortionary taxes, such as export duties. This is not a suitable solution for financing R&D. Part of it aims to improve productivity in export sectors, such as agriculture. However, how this is financed should not affect the economic viability and international competitiveness of the sector that could use these new technologies.

A partial way out of public sector funding restrictions is for the private sector to have a more significant share of R&D expenditure, utilizing its own resources. As we showed before, this is what is observed in developed economies. This seems obvious, but to accomplish this objective, the country needs science-based firms to be created in the first place. This, in turn, may require the support of public funds and the collaboration of public scientific institutions to spur entrepreneurial activity based on scientific ideas and discoveries. This occurred with Bioseres, a firm that now has its own lab (INDEAR) and is also involved in venture capital initiatives supporting biotechnology start-up companies. Initially, Bioseres received funds from the public systems to finance many of its bio projects (through FONTAR and FONARCEC), and INDEAR was a joint venture with CONICET[45]. So, it is like we need a well-developed system of collaboration between public and private actors in the scientific and entrepreneurship ecosystem so that public money in science could be highly effective in generating spillovers in terms of start-up creation, so it works as a multiplier by its effects on private ventures and private expenditures in R&D. We discuss issues associated with private-public collaboration next.

Private-public collaboration and cofinancing of science-based enterprises (SBE)

Even after numerous measures public institutions have taken to improve private-public collaboration in science-based business, the process by which a private company interacts with the scientific system remains cumbersome. On the one hand, it must be acknowledged that public innovation systems often lack the experience and capabilities to create start-ups that can rapidly grow and compete in international markets. That is why many public university spin-off mechanisms have not delivered the expected results, with a few exceptions. These deficiencies have been partly addressed by the surge of privately run incubators and accelerators, such as the mentioned cases of CITES, GRIDEX and SF-500, which have significantly improved the collaboration between private and public actors in linking science and entrepreneurship. These experiences need to be replicated and promoted by governments at both national and sub-national levels.

However, various other issues must be tackled for these new organizations to perform their job effectively. One key issue is the presence of specific rules that limit researchers from participating in companies as founders or having equity in these ventures. The regulation set up by CONICET in 2013 established restrictions to permanence in the research career when researchers exceeded 50% of the stock package and participated in the company's decision-making process. In September 2019, a new regulation was established that includes the possibility of obtaining a license for two years to participate in creating a science-based start-up. More recently, in 2022, these rules were further adapted, allowing the researcher to participate in the SBE for seven years, maintaining his position at CONICET. This added

[44] In the case of INTA, the research group involved in the project gets only 20% of the fees for these services. See O'Farrel et al (2022).
[45] This was also the case with GRIDEX and SF-500.

flexibility is relevant to avoid disincentivizing scientists to participate in private ventures subject to high uncertainty regarding their final economic viability.

A second key concern we have already mentioned is promoting the concurrence of private and public funding for science-based start-ups. These new privately run accelerators/VC institutions have effectively played a key role in this task. However, as shown in Table 16, public funding offered to these institutions was key for launching and starting their operations. This was done after the approval of the entrepreneurship law in 2017, which created a new funding instrument called FONDCE (Fondo Fiduciario para el Desarrollo del Capital Emprendedor). This mechanism has a design similar to that of Yuna in Israel and tries to function as a “Funds of Funds”. Its main objective was to support entrepreneurship by promoting public, private, and public-private institutions that would support start-ups through their various development stages. It initially had a budget of $1,000 million pesos (around 70 million USD), with the Secretariat of Small and Medium Enterprises and Entrepreneurs (SEPYME) as the enforcement authority and the Bank of Investment and Foreign Trade (BICE) as the operator of the funds.

The resources were divided into three funds: the Seed Fund, the Acceleration Fund, and the Expansion Fund. They offer loans, non-refundable contributions (ANR), venture capital contributions, and financial assistance. Entrepreneurs have to be associated with an incubator institution in the case of the seed Fund, an acceleration organization in the case of the Acceleration Fund (CITES and GRIDX were among the selected institutions), and a Venture Capital initiative in the case of the Expansion Fund. All three funds have also allocated resources to finance the operation costs of the intermediating institutions[46].

This program addressed a market failure: the scarcity of organizations that could effectively connect science and entrepreneurship to support science-based start-ups with global impact. To attract Venture Capital funds, we need a minimum scale of start-ups to be incubated, created, and accelerated. VC funds complement pre-seed and seed funding, enabling firms to expand and achieve their growth potential through various capitalization rounds. We observe this complementation between public funds and private venture capital in the most successful privately run accelerators described above (CITES, GRIDEX, and SF-500)[47].

Although it was well-conceived, the results of the FONDCE program were mixed in practice. On the one hand, it has helped foster the development of new incubator/acceleration/VC institutions that have played a critical role in identifying and mentoring/financing high-quality start-ups, especially those baked by new technologies and applied science. A key issue was that the program enabled the development of institutional capabilities in regions beyond Buenos Aires, such as Santa Fe, Córdoba, and Mendoza. Many of these entrepreneurial ventures have had a regional (Latin America) and global impact, and many of the acceleration and expansion funds have financed start-ups still in the market (Brizuela et al., 2022). On the other hand, as mentioned above, after 2018, budget restrictions and macroeconomic instability limited the effectiveness of the Fund. The Acceleration and Expansion Fund had committed resources in dollars, given that various expenditures faced by start-ups with a regional and global orientation are denominated in that currency (investment in marketing in foreign markets, intellectual property/patent

[46] As of August 2021, the Seed Fund selected 132 incubators to channel its funding to 1199 projects; in the case of the Acceleration Fund, they worked with 13 institutions that invested in 69 start-ups, while the Expansion Fund selected three Venture Capital organizations that supported 9 projects. While the incubators do not have to co-invest in the business, in the case of the accelerators, the co-investment arrangement was 2x1. For VC institutions, the objective was to create three instruments with a capitalization of 30 million each. FONDCE's initial capital investments would be up 12 million USD, while 28 million would come from private sources (60- 40% shares). For a more comprehensive evaluation of the FONDCE Fund, see Brizuela et al., (2022).

[47] Argentina's VC industry faces challenges beyond the fact that there may be too few start-ups to invest in. Economic instability has thinned domestic financial and capital markets, so reaching international financial actors and investors has been crucial for scaling up start-ups.

expenses, import of specific equipment, among others). The devaluation of the currency in 2018 has implied a significant reduction (measured in dollars) of the committed support (Brizuela et al. 2022).

Patents, technology licensing, and approval and registration conditions for commercialization

Another key policy area affecting science-based start-ups is patent regulation, technology licensing, and the approval and registration procedures for new products and processes. These regulations affect incentives to innovate and develop new technologies and the investment needed to produce and commercialize these new products.

Patents and technology licensing

Patents are a key instrument to promote innovation. As is well known, patents grant a limited-term property right during which the inventor has the right to exclude others from making, using, or selling their invention. If a patented technology or product has a market value, it represents a source of income/valuable asset for the inventor. When considering policies to promote scientific research done in public institutions that significantly impact private enterprise creation, patent and technology licensing regulations established by these public institutions are very relevant. They may or may not facilitate the application of the knowledge into practical and commercial products and services.

The first consideration is that in public research institutions like CONICET (and public universities), the intellectual property rights of inventions developed within this organization or using its resources typically belong to the institution. Scientists who developed the invention are recognized as inventors, but CONICET retains ownership. Co-ownership agreements must be established before patent filing if the research involves other institutions (e.g., universities, private companies, or international partners). If the patent is licensed or commercialized (see discussion below), CONICET distributes royalties following an established percentage, where a portion goes to the inventors, and another fund is for CONICET and its research institutions.

Though, in principle, these arrangements may work well despite not giving full ownership to the inventors, as they share a percentage of the potential licensing fees, in practice, the system faces many challenges that affect researchers, the institution itself, and the entrepreneurs/private ventures that may help to commercialize innovations.

These limitations are related to what we have been discussing so far: (i) The approval of new patents is very bureaucratic and slow. This is due to multiple levels of administrative review, within which the INPI (Instituto Nacional de la Propiedad Intelectual), plays a key role. Many inventors/innovative entrepreneurs mention that these institutions cannot evaluate their projects, given the novelty they bring in. Given the complexity of the patent process, the limited human and financial resources dedicated to patent management in public research institutions also represent a problem. In this way, delays in patent approval can weaken the country's competitiveness, as researchers and companies may seek faster alternatives abroad. (ii) As we indicated above, when researchers collaborate with universities, private companies, or foreign institutions, conflict arises as to how to share ownership. These disputes and prolonged negotiations can delay or cancel potential deals. (iii) Even more important, licensing a patent owned by CONICET or a public university to a start-up is very cumbersome. Some accelerator organizations propose that license agreements be standardized to avoid relying on individual decisions or case-by-case analysis, making the process more agile and less uncertain. Formalizing license and patent agreements is essential for venture capital funds to attract potential investors (Gonzalo et al., 2023). (iv) Last but not least, the reform implemented in 2022 also allowed the possibility that the founder-scientist of a science-based enterprise (SBE) could own more than 50% of the new company (the 2013 protocol set a maximum of 50%). This could be implemented under two conditions: either the researcher gives

CONICET 50% of the benefits corresponding to these shares, or CONICET gains a minority participation in the equity of the newly created firm. This last possibility has been subject to criticism. This is because equity participation of the state in SBE, even if it is a minority portion, could affect decision-making, reducing flexibility and efficiency (and there is also the potential risk of political influence). This could disincentivize the participation of external investors. A related issue is that the new protocol does not regulate under what circumstances the public institutions that own part of the EBS could sell those shares. One way out of these problems is to sign a contract that specifies those circumstances, and that equity participation gives no vote rights (Gonzalo et al., 2023).

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Regulations associated with approvals and certifications

Most companies that emerge from scientific-based ideas in fields like biotechnology, medicine, chemistry, mining, transportation, etc., must be subject to approval and registration of products and services derived from their research and development processes. In the case of Argentina, these approval procedures may involve many ministries and public agencies like the Ministry of Health, and its central agency for approval of new medicine products, ANMAT (Administración Nacional de Medicamentos, Alimentos y Tecnología Médica); Ministry of Agriculture and its various specialized agencies like SENASA (Servicio Nacional de Sanidad y Calidad Agroalimentaria) and DNMA (Dirección Nacional de Mercados Agrícolas) for the case of food products, to name a few. For innovative and disruptive inventions, efficiently registering these new products is complex since some organizations are often unprepared for the necessary dynamics in a startup or to serve innovative technologies globally.

One step toward solving these problems is for the government to establish a specialized unit within each of these government offices to facilitate the registration and approval requirements for science-based start-up products/processes. For example, by creating fast-track processes, the private sector can also propose regulatory changes to adjust to new realities resulting from technological innovations (Kantis and Angelleli, 2020).

An example of a novel and relatively efficient regulatory framework applied to biotechnology products, particularly those associated with transgenic transformation, was CONABIA (Comisión Nacional Asesora de Biotecnología Agropecuaria). In Argentina, this agency has imposed a high degree of compliance with the standards promoted by international organizations and regulations, which facilitates and encourages the investment and approval of GMOs (genetically modified organisms) by multinational companies with global operations. For example, this allowed the rapid approval of the HB4 seed, which was also certified in the USA, Brazil, and China.

4. Concluding remarks

Like many other LAC countries, Argentina must strengthen productivity growth to achieve a more dynamic development path. An essential ingredient for this to happen is to support the creation of firms with growth potential by promoting innovation and entrepreneurship. In this paper, we examine the innovation policies of Argentina by first analyzing the impact of existing grants and funds designed to promote innovation within private firms. We find that these subsidies have helped small and medium-sized firms expand their expenditure and labor allocation in innovation activities, which in turn have positively affected the development of new and improved products and production processes. This has supported an increase in employment and sales.

Nevertheless, quite more relevant in terms of expenditures and human resources allocated to R&D and innovation is the public scientific ecosystem given by universities, research institutions, and public labs. We ask to what extent these resources can also generate spillovers in entrepreneurship so that science-based enterprises (SBE) are created with regional and global impact. Considering this question, we describe these institutions' initiatives to collaborate with entrepreneurs and existing firms to promote technology transfer and spin-offs/start-ups out of scientific discoveries. We demonstrate that over the last decade, various universities and public research centers, such as INTA, have established technology transfer offices and incubator-like organizations within their organizational structures.

Though it is not easy to establish a quantitative metric to evaluate the results of these initiatives, the available qualitative information from interviews with key players and some indicators regarding the number of businesses incubated suggests that the results are somewhat below what was expected. While some of these incubators have ceased their operations, the ones that remain have achieved relatively few sustainable businesses. There are many reasons behind these mixed results. Many scientists harbor negative prejudices when evaluating a potential business idea, particularly when the metric used for evaluation is related to publications in academic journals, and some regulations limit their potential participation in such private ventures. In addition, the technology transfer/spin-off/incubator areas depend exclusively on public money to operate, and public support has been very volatile, subject to budget restrictions and economic crises. Furthermore, entrepreneurs complain that these public institutions lack the necessary skills to develop business strategies that make scientific ideas commercially sustainable.

In any case, this mixed experience has been relevant for the surge of a new generation of incubator /accelerator/VC institutions that have been quite active in recent years in reaching out to the scientific community and offering a more robust ecosystem where government/university institutions, researchers, entrepreneurs, and investors can collaborate and be more effective in terms of bridging the gap between science and businesses. A sector where this has been occurring with very interesting results regarding the generation of new science-based start-ups with global impact is biotechnology. The cases CITES, GRIDX, and SF-500, among others, are key examples. These institutions provide the necessary resources for start-ups to navigate the various stages of their development, including seed capital, follow-on funds, and eventually venture capital resources, and connect scientists with potential co-founder entrepreneurs. This, combined with training, mentoring, and a rigorous selection process, provides a stronger foundation for science-based start-ups to flourish. Having said this, it is also important to mention that these new institutions were in part the outcome of a decision by the government to redirect part of the innovation support not directly to private firms but channel this support through the intermediation of these new incubator/acceleration organizations where co-investment, business training, mentoring and strategic counseling for escalation/VC was also provided.

A key policy issue is ensuring the continuity of public funding for the scientific ecosystem and the incubator, accelerator, and venture capital organizations in a more stable macroeconomic environment. Besides this, a series of regulatory factors are also necessary: (i) facilitating scientists' participation in transfer technology initiatives and science-based start-ups; (ii) simplifying patent and technology licensing; (iii) improving protocols regulating the participation of public institutions the newly created firms; (iv) assisting start-ups in obtaining registration and government approval of new products. In this manner, a virtuous circle could be established between government incentives, science, entrepreneurship, and investors so that public money invested in financing R&D and innovation could have more substantial spillover effects on creating new firms with a global impact.

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