THE PRODUCTIVITY IMPACT OF INNOVATION ON INDUSTRY IN ARGENTINA

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1. General features of the work

2. Theoretical perspective I Background

3. Data | Methodology

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   - Descriptive statistics
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GENERAL FEATURES OF THE WORK

WORK PATH | OBJECTIVE | METHODOLOGICAL APPROACH | HYPOTHESIS | DATA SOURCES

WORK PATH

PICT-FONCYT 2019-2021: *Innovación, productividad y desigualdad laboral en la industria argentina.*

Article currently under revision in international Journal (English).

[Preliminary exercises with CDM model on Innovation-Wages: link conditioned by structural heterogeneity of local industry]

OBJECTIVE

To assess the innovation process in Argentine manufacturing firms and its impact on labour productivity.

MOTIVATION

Better understanding of constraints and contributions of innovation at firm-level, in a historical context of low growth and productivity, even in periods of industrial recovery.
As an exercise with a novel database and relatively unexploited model in Argentina.

METHODOLOGICAL APPROACH

CDM model (general model based on Crepon, Duguette & Mairesse, 1998): it combines firms' innovative decisions with innovation results and their impacts on labour productivity.

HYPOTHESIS

In the last decade, firms that have undertaken innovative processes have achieved significant innovation outputs, which have positively affected their labour productivity levels, irrespective of general industry conditions.

DATA SOURCES: Encuesta Nacional de Dinámica del Empleo y la Innovación (ENDEI, MINCYT – MTEySS).
- ENDEI I 2010-2012
- ENDEI II 2014-2016

THEORETICAL PERSPECTIVE | BACKGROUND

Innovation and poor economic performance of national economy:

To a large extent attributable to historically low productivity (particularly of manufacturing sector) within the framework of absence or weakness of processes of diffusion of technological innovations at levels that can stimulate structural change (Abeles & Amar, 2017):

- prevalence of activities of low technological complexity
- structural technological heterogeneity
- persistent productive disarticulation
- persistent macroeconomic restrictions

Studies based on innovation surveys repeatedly demonstrate that product and/or process innovation leads to better economic performance:

- European companies (Lööf et al., 2001; Mohnen et al., 2006).
- Peripheral economies find similar evidence (Arza and López, 2010; Chudnovsky et al., 2004; Raffo et al., 2008): highlighting difficulties these economies face when investing in innovation.

Limitations of background about innovation-productivity in local industry

- Data from the first years of the century, before the recovery experienced at the macroeconomic and sectoral level (Chudnovsky et al., 2004; Katz, 2000).
- Unexploited data collected after the end of a period of local industrial expansion (Pereira and Tacsir, 2017).

Own related background:

Innovation activities of Argentinean manufacturing firms are significantly associated with higher levels of productivity, wages, and job skills, in a magnitude that differs at sectoral and firm level due to structural heterogeneity (concerning the decision to innovate, using methods of quantile regression and ordinary least squares) (Gómez y Borrastero, 2018).

Historical difficulties in measuring the effects of innovation activities on productivity:

- Widely accepted approach: to model this link in an innovation function + a production function (Griliches,1979 and Pakes and Griliches, 1980 as seminal contributions).

- **Crépon, Duguette y Mairesse (1998)** first to empirically integrate the link *innovation efforts - innovation results - performance impact of innovation* **into a structural model** (CDM acronym).

This work:

Founded in adaptations to Latin America and Argentina of general CDM approach (Crespi and Zuniga, 2012).

DATA | METHODOLOGY

Data from the National Survey on Employment and Innovation Dynamics (ENDEI - MTEySS and MINCyT). Two survey rounds: ENDEI I (2010-2012) and ENDEI II (2014-2016).

ENDEI is an industry-specific innovation survey. It includes, innovative, labour, productive and organisational dimensions.

Sampling unit: firms registered in Argentine Pension System (SIPA in Spanish) stratified by size and sector.
Size: 10-25 /26-99 / 100 or more workers.
Sectors: ISIC-Rev. 3 and at 2-digit (4-digit in food and beverages sector).
Represent almost 19.000 firms in the manufacturing sector

Short-term sample. Data three years in length. Other examples with similar periods (Cozzarin, 2016; Crespi and Zuniga, 2012; Crespi et al., 2016; Raffo et al., 2008).
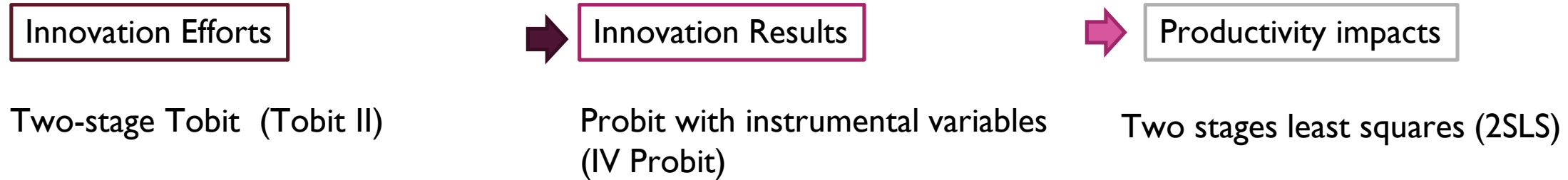
Samples for the estimations
ENDEI I (2010-2012): 3072 firms.
ENDEI II (2014-2016): 2589 firms.

CDM as a structural recursive model that defines innovation process in three phases

Model estimated for both the innovative and the non-innovative firms. Connect stages with latent variables.

| Innovation Efforts | ➡ Innovation Results | ➡ Productivity impacts |

Two-stage Tobit (Tobit II)

Probit with instrumental variables (IV Probit)

Two stages least squares (2SLS)

Probability to innovate (*)

Probability to introduce innovations in the market

Labour Productivity

$$Inno_{it} = \begin{cases} 1 & if \ Inno^*_{it} = X'_{it}\alpha_t + e_{it} > 0 \\ 0 & otherwise \end{cases}$$

$$IR_{ijt} = I\_exp^{*\prime}_{it}\gamma_{jt} + Z'_{it}\delta_{jt} + \tau_{ijt}$$

$$L\_prod_{it} = IR^*_{ijt}{}'\vartheta + T'_{it}\pi_t + s_i$$

Innovation intensity

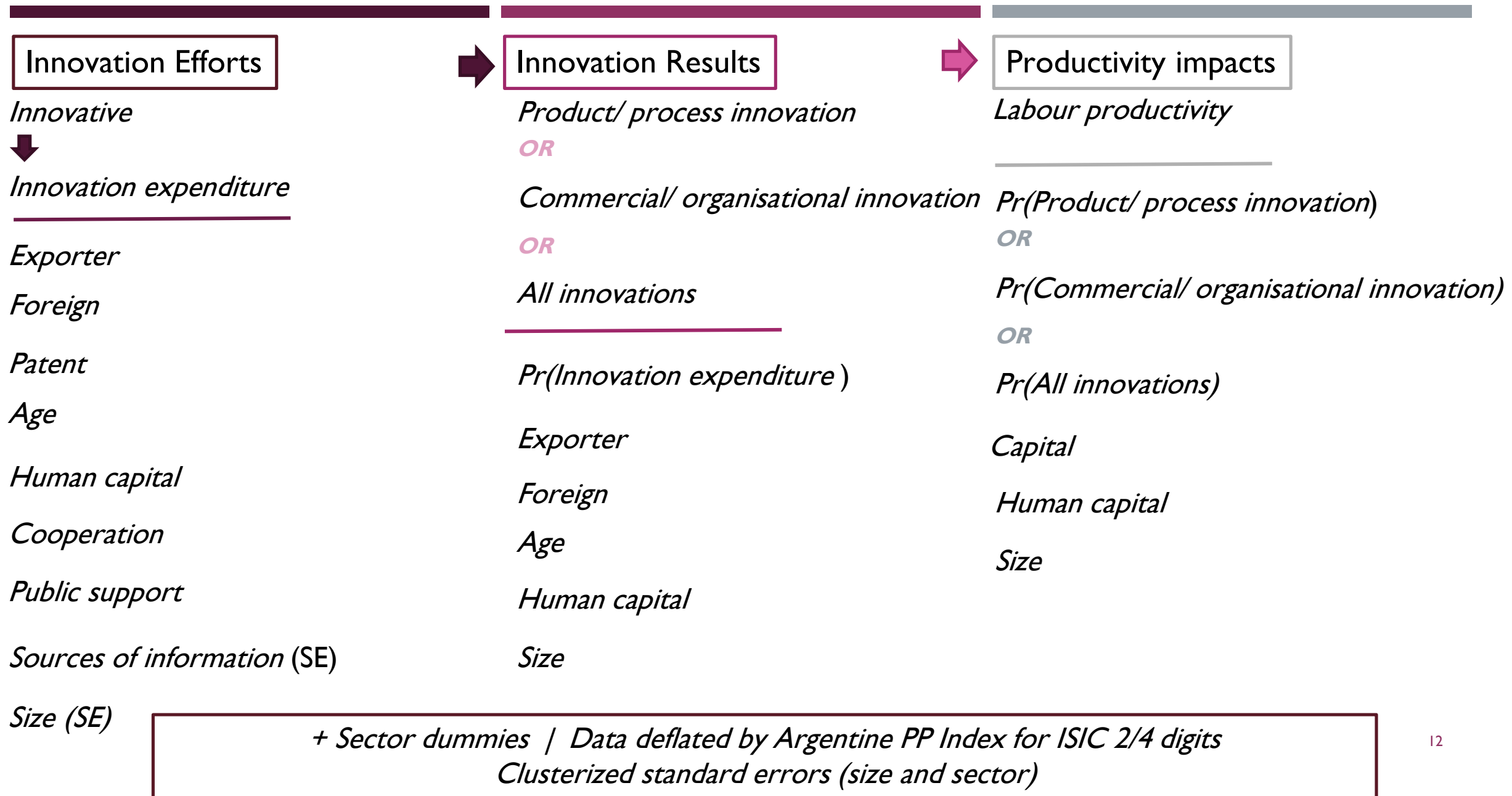$$I\_exp_{it} = \begin{cases} I\_exp^*_{it} = W'_{it}\beta_t + v_{it} \\ \quad if \quad Inno_{it} = 1 \\ \\ 0 \quad otherwise \end{cases}$$

CDM main assumptions

Models innovation process for every firm

A Linear innovation process

No feedback effects

METHODOLOGY

Innovation Efforts → **Innovation Results** → **Productivity impacts**

Innovation Efforts	Innovation Results	Productivity impacts
Innovative ↓ *Innovation expenditure*	*Product/ process innovation* OR *Commercial/ organisational innovation* OR *All innovations*	*Labour productivity*
Exporter	*Pr(Innovation expenditure)*	*Pr(Product/ process innovation)* OR
Foreign	*Exporter*	*Pr(Commercial/ organisational innovation)* OR
Patent	*Foreign*	*Pr(All innovations)*
Age	*Age*	
Human capital	*Human capital*	*Capital*
Cooperation	*Size*	*Human capital*
Public support		*Size*
Sources of information (SE)		
Size (SE)		

+ Sector dummies | Data deflated by Argentine PP Index for ISIC 2/4 digits
Clusterized standard errors (size and sector)

EMPIRICAL RESULTS

Table 1. Descriptive statistics

Dummy variables (frequencies) (2)	2010-2012	2014-2016
Innovative	60.1	70.1
Exporter	38.4	32.8
Foreign capital	7.9	5.3
Patent	6.3	7.9
Age	7.5	15.5
Product/process innovation	60.0	66.6
Commercial/organisational innovation	30.0	36.1
All innovations	61.0	67.8

Source: own elaboration on ENDEI data.

Table 1. Descriptive statistics

Periods	2010-2012				2014-2016			
Continuous variables	mean	sd	Min	Max	mean	sd	Min	Max
Innovation expenditure (1)	7.50	31.86	0.00	1246.29	19.71	56.09	0.00	866.17
Human capital (2)	6.37	3.53	1.76	21.57	8.06	3.54	2.54	19.79
Cooperation	33.48	11.84	8.33	78.57	39.01	12.04	15.15	75.00
Public support	22.09	11.29	5.80	72.73	17.90	8.95	2.63	44.12
Sources of information	25.73	27.85	0.00	100.00	24.90	25.64	0.00	100.00
Size	73.32	102.54	2.00	400.00	74.01	101.44	2.00	400.00
Labour productivity (1)	244.83	294.20	2.32	3454.99	476.66	614.65	2.81	8614.46
Capital (3)	35.30	148.00	0.00	3960.00	30.06	169.00	0.00	4890.00

ECONOMETRIC RESULTS

The decision to innovate and the innovation intensity

Table 2. Decision to invest in innovation and innovation intensity

Periods	2010-2012		2014-2016	
Variables	Probability to invest in innovation (1)	Expected innovation expenditure (2)	Probability to invest in innovation (1)	Expected innovation expenditure (2)
Exporter (Exp)	0.044***	0.380***	0.043***	0.623***
	(0.016)	(0.145)	(0.015)	(0.152)
Foreign capital (F_cap)	0.040	0.826***	0.044*	0.829***
	(0.034)	(0.318)	(0.026)	(0.279)
Patent (Pat)	0.096**	0.876**	0.299***	2.968***
	(0.045)	(0.387)	(0.004)	(0.097)
Age	-0.016	-0.206	-0.009	-0.044
	(0.016)	(0.138)	(0.012)	(0.136)
Human capital (H_cap)	0.034	1.733	0.057	0.658
	(0.402)	(3.623)	(0.153)	(1.779)
Cooperation (Coop)	0.131	1.215	0.017	0.073
	(0.130)	(1.130)	(0.059)	(0.623)
Public support (Pub_s)	0.115	0.935	0.096**	0.354
	(0.086)	(0.789)	(0.045)	(0.476)
Sources of information (S_info	0.009***	-	0.049***	-
	(0.002)		(0.002)	
Size	0.030***	-	0.007	-
	(0.009)		(0.007)	
Sector dummies	Yes		Yes	

Table reports the average marginal effects (AME) over the probability to invest in innovation and the expected value of innovation per worker

The decision to innovate and the innovation intensity (cont'd)

Table 2. Decision to invest in innovation and innovation intensity

Periods	2010-2012	2014-2016
ln sigma	0.362***	0.384***
	(0.003)	(0.000)
athrho	-0.140*	-0.169***
	(0.008)	(0.005)
Log pseudo likelihood	-4,431.30	-3,658.65
Rho	-0.139	-0.167
Adjusted R2	0.480	0.746
Consored observations	1325	764
Uncensored observations	1747	1825

Notes: *p<0.01, ** p<0.01, *** p<0.01. Reported estimates are (1) Average marginal effect on the probability to invest in innovation; (2) Average marginal effect on the unconditional expected value of innovation. Clustered standard errors in parentheses (at sector and size levels). Sector dummies (not reported) were included in the estimation.

Source: own elaboration on ENDEI data.

The innovation results

Table 3. Innovation results

Periods	2010-2012			2014-2016		
Variables	Product/ process innovation	Commercial/ organisational innovation	All innovations	Product/ process innovation	Commercial/ organisational innovation	All innovations
Predict (I_exp)	0.025***	0.019***	0.025***	0.027***	0.039***	0.023***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Exporter (Exp)	-0.003	-0.036***	-0.008	0.020*	0.024	0.013
	(0.012)	(0.012)	(0.011)	(0.012)	(0.020)	(0.009)
Foreign capital (F_cap)	-0.095***	-0.051*	-0.090***	-0.057*	0.033	-0.062**
	(0.023)	(0.027)	(0.026)	(0.030)	(0.033)	(0.026)
Age	0.009	-0.020	0.002	-0.001	0.018	0.003
	(0.014)	(0.019)	(0.013)	(0.013)	(0.024)	(0.010)
Human capital (H_cap)	-0.541*	-0.496	-0.316	-0.081	0.211	-0.042
	(0.302)	(0.343)	(0.291)	(0.145)	(0.320)	(0.147)
Size	-0.005	0.000	-0.004	0.006	0.014*	0.008**
	(0.007)	(0.008)	(0.007)	(0.004)	(0.008)	(0.004)
Sector dummies	Yes	Yes	Yes	Yes	Yes	Yes

Table reports the average marginal effects (AME) over the probability to introduce new/improved innovations in the market

Exporter coefficient
Not signifficant

The innovation results (cont'd)

Table 3. Innovation results

Periods	2010-2012			2014-2016		
Log pseudo likelihood	-8635.00	-9373.57	-8579.83	-6136.99	-6994.97	-6038.08
Wald-chi2	2621.58***	2050.14***	3293.27***	2668.35***	1709.42***	2543.65***
Wald (exogeneity)	354.06***	267.36***	364.4***	68.81***	52.23***	59.75***
Correct classification	93.33%	73.50%	94.01%	95.52%	69.49%	96.87%
Observations	3072	3072	3072	2589	2589	2589

Notes: *p<0.01, ** p<0.01, *** p<0.01. (1) Each column represents a different IV probit estimation, considering the innovation result categories (see data section). Reported estimates are average marginal effects on the probability to obtain innovation results.

Clustered standard errors in parentheses (at sector and size levels). Sector dummies (not reported) were included in the estimation.

Probit coefficients reported in Annex Table A3.

Source: own elaboration on ENDEI data.

The productivity impacts

Table 4. Innovation impacts on labour productivity

Periods	2010-2012			2014-2016		
Variables	From product/ process innovation	From commercial/ organizational innovation	From all innovations	From product/ process innovation	From commercial/ organizational innovation	From all innovations
Predict (Pr_pr)	0.138*** (0.041)	-	-	0.199*** (0.043)	-	-
Predict (Com_org)	-	0.319*** (0.075)	-	-	0.562*** (0.085)	-
Predict (All_I)	-	-	0.130*** (0.041)	-	-	0.184*** (0.041)
Capital (Cap)	0.002 (0.001)	0.001 (0.001)	0.002 (0.001)	0.000 (0.001)	-0.001 (0.001)	0.000 (0.001)
Human capital (H_cap)	1.212 (1.008)	1.169 (1.017)	1.194 (1.006)	1.494* (0.852)	1.165 (0.905)	1.500* (0.855)
Size	0.106*** (0.018)	0.101*** (0.019)	0.106*** (0.018)	0.135*** (0.020)	0.114*** (0.021)	0.137*** (0.020)
Sector Dummies	Yes	Yes	Yes	Yes	Yes	Yes

Table reports the average marginal effects (AME) over the labour productivity value

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The productivity impacts (cont'd)

Table 4. Innovation impacts on labour productivity

Periods	2010-2012			2014-2016		
F	15.39***	14.89***	15.18***	28.87***	33.73***	28.75***
Adjusted R2	0.065	0.039	0.062	0.095	0.0420	0.096
Endogeneity test	9.89***	12.09***	9.89***	8.19***	25.59***	6.77***
Heteroskedasticity test	61.73***	65.71***	62.76***	33.31***	24.88*	33.77**
Observations	3072	3072	3072	2589	2589	2589

Notes: *p<0.01, ** p<0.01, *** p<0.01. (1) Each column represents a different IV regression, considering as alternative covariates the innovation result categories (see data section). Reported estimates are average marginal effects of innovation results on (log) labour productivity. Clustered standard errors in parentheses (at sector and size levels). Sector dummies (not reported) were included in the estimation.

Source: own elaboration on ENDEI data.

DISCUSSION

MAIN CONTRIBUTIONS

1. Application of CDM model to Argentinean manufacturing firms on a novel database which combines innovation variables with productive, organizational, labour, market and institutional dimensions.

2. Estimation over two survey rounds (two different periods for manufacturing sector).

3. Identification of constraints and innovation potentials of local industry:
- Relative disparity innovation efforts - innovation outputs.
- Lack of influence of certain microeconomic determinants on the innovative decisions of firms.
- Significant and positive link between innovation and firm productivity, even in a context of idiosyncratic conditions associated with the innovation process.

4. Contribution to regional literature on the subject.

5. Contribution to review and formulation of specific policies.

MAIN CONTRIBUTIONS

5. The presence (absence) of certain conditions can foster (restrain) the underlying dynamics that connect the decisions to innovate with the firms productive performance.

6. Exporting: significant and positive influence on the decision to innovate and the intensity of that innovation in 2010-2012 and 2014-2016. Yet, does not affect innovation outputs. Background: only over complementarity innovation efforts-exporting condition (Lugones, Suárez, Le Clech, 2007; Brambilla and Pacheco, 2018).

7. Foreign capital: not a greater likelihood to invest in innovation (yet higher expected innovation expenditures) combined with less probability of achieving innovation results.

8. Firms' size: few significant effects on the probability of investing (only in 2010-2012) and the chances of obtaining an innovation (only "all innovations" during 2014-2016). Yet, larger firms show higher productivity both periods as in Raffo, et al. (2008). Economies of scale.

9. Changing nature of the impact of public funding on the likelihood to invest in innovation. In 2010-2012 no significant impact, but for 2014-2016 stand as a condition to promote these investments. Needs further in-depth analysis.

CONSTRAINTS, SHORTCOMINGS AND FUTURE LINES OF RESEARCH

External constraints:

From Data: Missing variables
Not panel structure

From Model: Assumption of linnearity of innovation process
Time frame of effects of innovation process

Application shortcomings:

Additional potential sources of endogeneity.
Other determinants of link *innovation efforts - innovation results - economic performance*.

Future lines of research:

Conditions that structural heterogeneity of Argentine industry can impose on the results of this type of measurement.

Influence of temporal links between the stages of innovative process and its productive impact, on this type of measurement.

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THANK YOU!

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APPENDIX

Table A1. Argentina's GDP per cápita anual growth between decades

1960	2.3%
1970	1.1%
1980	-2.3%
1990	2.8%
2000	2.4%
2010	-0.7%

Note: Constant LCU.

Source: WDI. The World Bank. Access: April 2021.

Table A2. Variable definitions

I_exp	Innovation expenditure	Innovation expenditure per worker at constant values in 2010 (2010-2012 estimation) or in 2014 (2014-2016 estimation). For this variable we include the categories of innovation activities defined in ENDEI data (in-house and external R&D, expenditure in machinery & equipment and hardware & software, technology transfer, design & engineering, consultancy, training). This expenditure is estimated for all the innovation outputs. We use natural logarithms of the variable in the regressions.
Pr(I_exp)	Predict (I_exp)	Predicted values for the variable I_exp when estimating equation (1)
Innov	Innovative	Innovative firm. Dummy equal to 1 if the firm invested in at least one kind of innovation in 2010 (for estimation 2010-2012) or in 2014 (estimation 2014-2016).
Exp	Exporter	Dummy equal to 1 if the firm exports (in each estimation period).
F_cap	Foreign capital	Dummy equal to 1 if the firm has a foreign participation of 1 percent or above (in each estimation period).
Pat	Patent	Dummy equal to 1 if the firm has been granted with at least one patent (in each estimation period).
Age	Age	Dummy equals to 1 if the firm has 10 years old or more in the market (2010-2012 estimation). Due to changes in the variable coding in ENDEI data, for the estimation of 2014-2016 period, corresponds 9 years old or more.
H_cap	Human capital (1)	Percentage of workers with professional skills. Average of firms for the same sector and the same size categories (in each estimation period). We use this average ratio instead of including the share of professional skills reported by the firm to deal with potential endogeneity issues.
Coop	Cooperation (1)	Percentage of firms that cooperate with others for innovation activities, estimated for the same sector and the same size categories (in each estimation period). We use this average ratio instead of including the collaboration activities reported by the firm to deal with potential endogeneity issues.
Pub_s	Public support (1)	Percentage of firms that received public support programs for innovation, estimated for the same sector and the same size categories (in each estimation period). We use this average ratio instead of including the financial support status reported by the firm to deal with potential endogeneity issues.
S_info	Sources of information (2)	Percentage of external sources of information that the firm uses to develop its innovation activities. The survey includes nine alternative sources that represent 100 percent (suppliers/ customers; competitors/ other firms; consultants; public and/or private universities; public institutions of science and technology; Internet and industry forums; chambers and business associations; trade fairs, conferences, exhibitions, congresses; technical publications, catalogs, and academic journals).
Size	Size (1)	Firm size. Total employment in 2010 (estimation 2010-2012) or in 2014 (estimation 2014-2016). We use natural logarithms in the regressions.
Pr_pr	Product/ process innovation	Dummy equal to 1 if the firm reported that it introduced and/or significantly improved products and/or processs. Due to the construction of the variable in the database, this indicator accounts for innovation results over the entire periods (2010-2012 and 2014-2016).
Pr(Pr_pr)	Predict (Pr_pr)	Predicted values for the variable Pr_pr when estimating equation (2)
Com_org	Commercial/ organisational innovation (3)	Dummy equal to 1 if the firm reported that has introduced a new commercial channel and/or implemented significant organizational changes. This indicator accounts for innovation results over the entire periods (2010-2012 and 2014-2016).
Pr(Com_org)	Predict (Com_org)	Predicted values for the variable Com_org when estimating equation (2)
All_I	All innovations	Dummy equal to 1 if the firm reported that has introduced at least one innovation result (i.e. product/ process/ commercial/ organisational innovation). This indicator accounts for innovation results over the entire periods (2010-2012 and 2014-2016)
p_All_I	Predict (All_I)	Predicted values for the variable All_I when estimating equation (2)
L_prod	Labour productivity	Labour productivity. Value added per worker at constant values in 2012 (for estimation 2010-2012) or in 2016 (estimation 2014-2016). We use natural logarithms in the regressions.
Cap	Capital (6)	Fixed investment per worker at constant vaues. For 2010-2012 estimation we use investment in machinery and equipment per worker during 2010-2011. Due to data restrictions for 2014-2016 we use other noncurrent expenditures during 2014-2015. We replace 0 values with 0.00001 to avoid missing observations and we use natural logarithms in the regressions.

Note: definitions based on ENDEI data. (1) Definition adapted from Crespi, Tacsir and Vargas (2016); (2) adapted from Arza and López (2010); (3) adapted from Raffo, Lhuillery, and Miotti (2008).

Table A3. Innovation efforts by categories

Periods	2010-2012		2014-2016	
Innovation activities	Firms that reported innovation expenditures	Average share on total innovation expenditure (1)	Firms that reported innovation expenditures	Average share on total innovation expenditure
In-house R&D	0.229	39.79	0.293	41.12
External R&D	0.072	25.05	0.077	22.13
Machinery & equipment	0.428	74.59	0.479	71.70
Hardware & software	0.197	17.77	0.245	19.14
Technology transfer	0.032	28.73	0.029	17.65
Design & engineering	0.164	27.92	0.281	37.45
Consultancy	0.140	24.92	0.192	26.17
Training	0.147	10.23	0.155	10.72

Note: Estimation sample (2010-2012): 3072; (2014-2019): 2589. (1) Average shares should not be added.

Source: own elaboration on ENDEI data.

Table A4. Innovation results. IV probit coefficients

Periods	2010-2012			2014-2016		
Variables	Product/ process	Commercial/ organisational	All innovations	Product/ process	Commercial/ organisational	All innovations
Predict (I_exp)	0.363***	0.227***	0.372***	0.436***	0.246***	0.473***
	(0.008)	(0.006)	(0.009)	(0.011)	(0.007)	(0.012)
Exporter (Exp)	0.031	-0.086*	0.003	0.217	0.081	0.185
	(0.067)	(0.046)	(0.068)	(0.141)	(0.070)	(0.143)
Foreign capital (F_cap)	-0.465***	-0.159	-0.464***	-0.500**	0.118	-0.658***
	(0.129)	(0.115)	(0.146)	(0.226)	(0.125)	(0.211)
Age	0.025	-0.080	-0.012	-0.013	0.063	0.046
	(0.071)	(0.064)	(0.073)	(0.139)	(0.087)	(0.155)
Human capital (H_cap)	-2.593*	-1.496	-1.521	-0.886	0.740	-0.606
	(1.507)	(1.177)	(1.459)	(1.634)	(1.199)	(2.142)
Size	0.011	0.027	0.016	0.064	0.050*	0.116**
	(0.035)	(0.030)	(0.037)	(0.049)	(0.027)	(0.055)
Constant	-1.139***	-1.483***	-1.121***	-2.402***	-2.431***	-2.744***
	(0.152)	(0.124)	(0.147)	(0.276)	(0.169)	(0.300)
Obs.	3072	3072	3072	2589	2589	2589

Notes: *$p<0.01$, ** $p<0.01$, *** $p<0.01$. Reported estimates are probit coefficients for each innovation results equation. Clustered standard errors in parentheses (at sector and size levels). Sector dummies (not reported) were included in the estimation.
Source: own elaboration on ENDEI data.