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Competition effect on innovation and productivity
The Portuguese case

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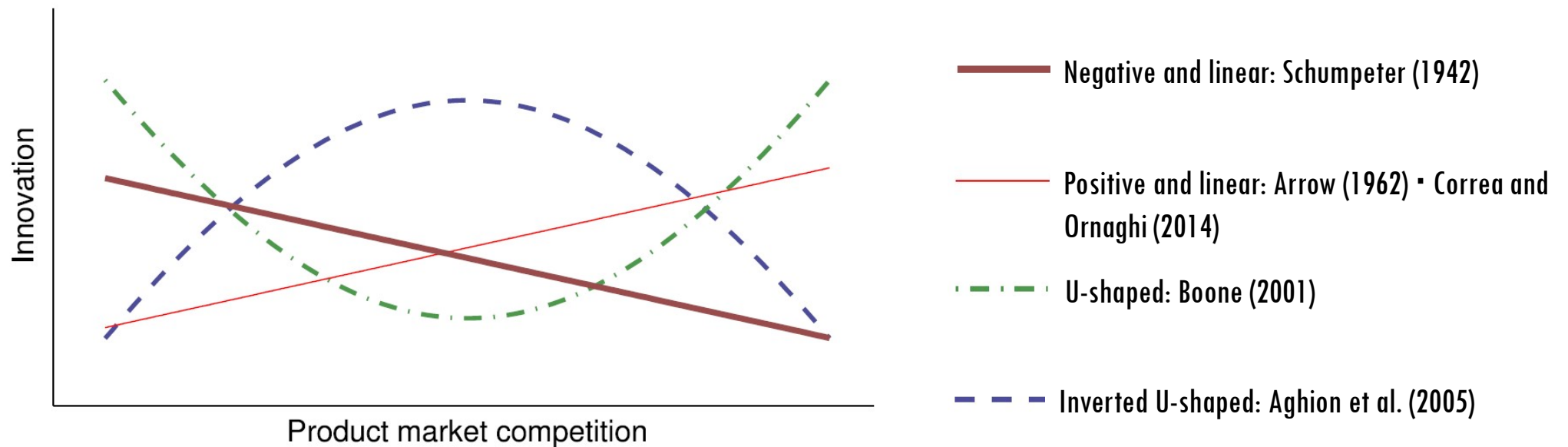
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1. Objective

- Impact assessment

  - Competition ➡ Innovation: Patent applications

  - Competition ➡ Productivity: Total Factor Productivity (TFP) and Labour Productivity (LP)

- Scope

  - Portuguese firms

  - 2007 - 2015

2. Background theory │ Competition effect on innovation

Figure 1. Theoretical relationship between competition and innovation

Legend:
- Negative and linear: Schumpeter (1942)
- Positive and linear: Arrow (1962) ⋅ Correa and Ornaghi (2014)
- U-shaped: Boone (2001)
- Inverted U-shaped: Aghion et al. (2005)

Axes: Innovation (y-axis), Product market competition (x-axis)

Source: Im et al. (2015:79)

2. Background theory │ Competition effect on productivity

Figure 2. Theoretical relationship between competition and productivity

Positive and linear: Haskel (1991) · Nickell (1996) · Kato (2009) · Correa and Ornaghi (2014)

Inverted U-shaped : Okada (2005) · Inui et al. (2012) · Aghion et al. (2017)
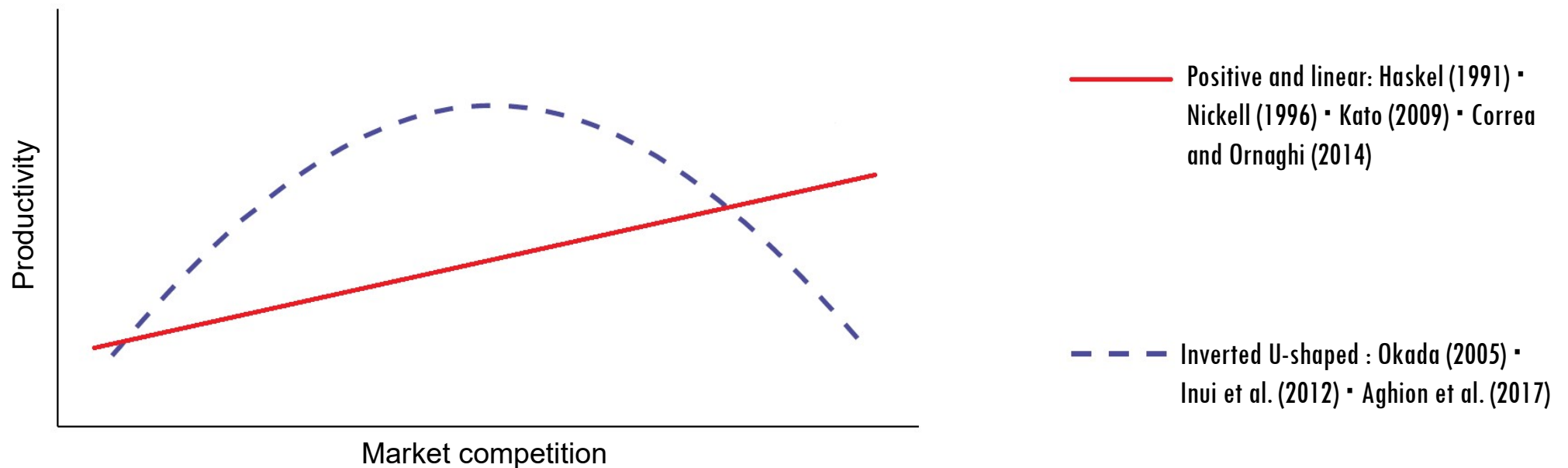
Source: Authors' own elaboration.

2. Background theory | Measuring competition

Market Share

- Relative size of a firm in an industry in terms of the proportion of total output (OECD, 1993)
- Herfindahl (1950) and Hirschman (1945) Index (HHI)

$$HHI = \sum_{i=1}^{n} (s_i)^2$$

Where:
- s_i = relative measure of the economic activity
- $\sum_{i=1}^{n} s_i = 1$

Market Power

- Firms' ability to control, raise and maintain price above the level that would prevail under perfect competition (OECD, 1993)
- Lerner (1934) Index (LI)

$$LI = \frac{P - MC}{P}$$

Where:
- P = Price
- MC = Marginal cost

2. Background theory | Measuring competition

Market Power versus Competition index

- The LI ranges between 0 and 1, where 0 indicates perfect competition and values above 0 some degree of market power
- $\triangle$ LI index $\rightarrow$ $\triangledown$ level of competition (higher level of market power)
- Competition measures ($c_{j,t}$) is the the inverse relationship of LI

$$c_{j,t} = 1 - \frac{1}{N_{j,t}} \sum_{i \in j} LI_{i,t}$$

Where:

- i : indexes firm,
- N: number of firms in industry j in year t

- Values near to 1 indicate a higher level of competition and those close to 0 a higher level of market power

2. Background theory │ Measuring competition

Issues with Lerner Index

- Marginal cost is not directly observed (Correa and Ornaghi, 2014) and it is not easy to measure empirically (OECD, 1993)

- LI doesn't cover fixed costs (Lindenberg and Ross, 1981) - marginal cost = variable costs

- An alternative is the price cost margin (Aghion et al., 2005) or profitability index (Correa and Ornaghi, 2014) - $\pi_{i,t}$

$$\pi_{i,t} = \frac{operating\ profit_{i,t} - financial\ cost_{i,t}}{sales_{i,t}}$$

- Where the operating profits less financial cost is similar to EBIT (Earnings Before Interest and Taxes) or EBITDA less depreciation and Amortization

3. Data

- Sample: 654 Portuguese firms
- Sectors: 208 NACE 4-digits
- Period: 2007 – 2015 (panel with 9 years)
- Selection: only firms with patent application at national and international level

Type of data	Source
Financial data	AMADEUS (Bureau van Dijk)
Patent application	AMADEUS (Bureau van Dijk)
R&D tax incentive	Portuguese tax and customs authority's statistical department (Portal das Finanças)
Direct public support to RDI	Information System of the Portuguese National Strategic Reference Framework (NSRF) 2007-2013 Incentive Systems

4. Methodology and conceptual framework

▫ Baseline framework: Aghion et al. (2005) and Correa and Ornaghi (2014)

▫ Competition indicator: $c_{j,t} = 1 - \dfrac{1}{N_{j,t}} \sum_{i \in j} \pi_{i,t};$ $\qquad$ $where\ \pi_{i,t} = \dfrac{EBIT_{i,t}}{sales_{i,t}}$

▫ Profitability index ($\pi_{i,t}$) of the most representative firms in the Portuguese economy by NACE code 4-digit

▫ The most representative firms (around 95,593 firms) → 92% of the total sales of the sectors under analysis

▫ EBIT (Earnings Before Interest and Taxes) is used as an equivalent to "operating profits less financial cost"

4. Methodology and conceptual framework

Innovation function

- Y = Patent applications

- Panel data + Count data model = Poisson regression model: $\mu_{i,t} = E(y_{i,t}|x_{i,t}) = \exp(x_{i,t}\beta)$

- Explanatory variables:
  - Competition level
  - Past innovative performance = growth rate of patent stock per employee [estimated using the Perpetual Inventory Method (PIM)];
  - Firm size = number of employees (Scherer, 1965; Crépon et al., 1998)
  - Qualification of human resources (Beneito et al., 2014) = labour cost per employee
  - Firm age (Beneito et al., 2014)
  - Access to public support (Tang, 2006; Chan, 2010; Rizzo and Ramaciotti, 2014) = 1 if the firm received any kind of direct or indirect public support to R&D or innovation (RDI); 0 otherwise.

4. Methodology and conceptual framework

Productivity function

- Y = Labour productivity (LP): value added per employee
- Y = Total Factor Productivity (TFP) ← Cobb-Douglas Production Function

- Panel data + Linear regression model: $y_{i,t} = \beta_0 + x_{i,t}\beta + \varepsilon_{i,t}$, where $\varepsilon_{i,t} = \alpha_i + u_{i,t}$

- Explanatory variables:
  - Competition level
  - Firm size (Crépon et al., 1998)
  - Qualification of human resources (Crépon et al., 1998) = labour cost per employee
  - Stock of patent applications per employee (Crépon et al., 1998) = [estimated using the Perpetual Inventory Method (PIM)];
  - Physical capital per employee (Crépon et al., 1998) = tangible fixed assets per employee
  - Access to public support (Sissoko, 2011) = 1 if the firm received any kind of direct or indirect public support to R&D or innovation (RDI); 0 otherwise.

5. Results │ Descriptive Statistics

Figure 3. Sample description: size, age and region
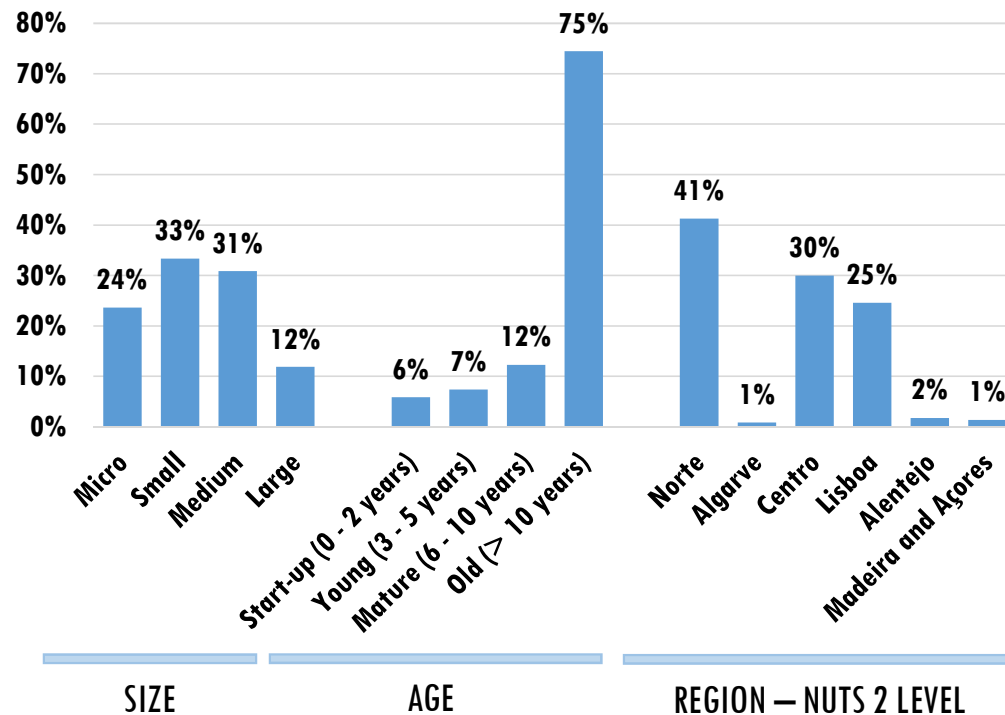
Main conclusion:

- Sample mainly composed by SMEs (88%), by firms with more than 10 years old (75%) and located in Norte (41%), Centro (30%) and Lisboa region (25%)

Source: Authors' own elaboration.

5. Results | Descriptive Statistics

Table 1. Patent versus competition level, by main economic activity

SECTION	N. Firms		Competition level		N° Patent		Patent by firm	
	Total	% Total	Average	Ranking	Total	% Total	Average	Ranking
C. Manufacturing industry	429	65.6%	0.9374	2	1 902	67.3%	4.4	3
F. Construction	22	3.4%	0.9337	3	41	1.5%	1.9	7
G. Trade, repair of automobiles and motorcycles	26	4.0%	0.9470	1	80	2.8%	3.1	4
J. Information and communication	41	6.3%	0.9043	5	112	4.0%	2.7	5
M. Specialized, scientific and technical activities	96	14.7%	0.8868	6	543	19.2%	5.7	1
N. Administrative and support services activities	18	2.8%	0.9117	4	97	3.4%	5.4	2
Other sectors	22	3.4%	0.8554	7	52	1.8%	2.4	6
TOTAL	654				2 827		4.3	

Source: Authors' own elaboration based on AMADEUS database.
Note: Other sectors included firms in the following sections: A. Agriculture, Forestry and Fishing; B. Extractive industries; D. Production and distribution of electricity, gas, steam and air conditioning; E. Production and distribution of water, sanitation, waste management and depollution; H. Transport and storage; I. Accommodation and restoration; K. Financial and insurance activities; L. Real estate activities; P. Teaching and; Q. Human health and social action

Main conclusions:

- Main sectors (86.5%): manufacturing industry (66%) and specialized, scientific and technical activities (15%)

- Higher level of competition: trade and manufacturing

- Low level of competition: services sectors

- On average firms submitted 4.3 patents applications and 39% of the sample hasn't submit any patent applications between 2007 and 2015

Santos, Cincera, Neto and Serrano | 4 May 2018

5. Results │ Innovation — Patent application

Table 2. Results of Poisson regression: N° of patent applications (<u>all sectors</u>)

Variables	Random effects		Fixed effects		Random effects		Fixed effects		Random effects		Fixed effects	
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
Competition level	1.493	(3.093)	1.916	(3.349)	-		-		-56.70**	(25.83)	-58.69**	(26.25)
Competition level (squared)	-		-		-		-		33.25**	(14.89)	34.65**	(15.13)
Δ Competition level (growth rate)	-		-		5.397**	(2.355)	5.476**	(2.375)	-		-	
Constant	-2.674	(2.564)	-		-1.141***	(0.188)	-		22.14**	(10.70)	-	
Observations	5,886		3,672		5,232		3,048		5,886		3,672	
Number of id	654		408		654		381		654		408	
Log pseudolikelihood	-4 664.47		-3 276.79		-4 078.84		-2 763.90		-4 656.24		-3 268.09	

Source: Authors' own elaboration. Note: Robust standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. When fixed-effects model is reported it refers to conditional fixed-effects.
Year, region and NACE 2 digits dummy are included in the model but not reported.

Main conclusions:

- Competition level: non-linear relationship (U-shaped) effect on innovation, as predicted by Boone (2001)

- Growth rate of competition level: positive and linear effect on innovation

5. Results | Innovation – Patent application

Table 3. Results of Poisson regression (conditional fixed-effects estimator)
N° of patent applications (all sectors)

Variables	Model 7		Model 8		Model 9	
Competition level	-93.61***	(32.04)	-96.33***	(34.38)	-	
Competition level (squared)	55.22***	(18.66)	56.74***	(20.26)	-	
Δ Competition level (growth rate)	-		-		5.958***	(2.072)
Firm size - Log (n° employee)	0.998***	(0.248)	0.991***	(0.257)	0.961***	(0.243)
Firm age - Log (n° year)	-0.631**	(0.313)	-0.544*	(0.329)	-0.483	(0.340)
Δ Patent stock per employee	0.549**	(0.262)	0.555**	(0.279)	0.532**	(0.260)
Log (average salary per employee) - "T-1"	0.403	(0.403)	0.353	(0.402)	0.308	(0.360)
Received national public support for RDI - "T"	0.383***	(0.125)	-		-	
Received national public support for RDI - "T-1"	-		0.174*	(0.0944)	0.191**	(0.0925)

Source: Authors' own elaboration.

Note: Robust standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

N° observations = 2,609. Log pseudolikelihood: Model 2 = -21,449.18 | Model 4 = -2.161,17 | Model 6 = -2.168,18

Year dummy included in the model, but not reported.

Main conclusions:

- Direct and short-term effect of competition is negative

- Medium-long term effect of competition is positive: faced to an increase of competition in the market, firms are forced to innovate to overcome competition pressure

- Positive effect: firm size, patent stock per employee, public support

- Negative effect: firm age

5. Results | Productivity

Table 4. Results of panel regression model: Productivity function (Log TFP), all sectors

Variables	Random effects Model 10		Fixed effects Model 11		Random effects Model 12		Fixed effects Model 13		Random effects Model 14		Fixed effects Model 15		Random effects Model 16		Fixed effects Model 17	
Log (Competition level)	-0.0442	(0.122)	-0.0475	(0.123)	-		-		-		-		-0.202	(0.181)	-0.202	(0.180)
Log (Competition level - squared)	-		-		-		-		-		-		-0.423	(0.530)	-0.413	(0.531)
Δ Log (Competition level) in "T"	-		-		0.0831	(0.0677)	0.0850	(0.0671)	-		-		-		-	
Δ Log (Competition level) in "T-1"	-		-		-		-		0.228**	(0.0891)	0.229***	(0.0884)	-		-	
Constant	1.583***	(0.0300)	1.894***	(0.0114)	1.587***	(0.00518)	1.904***	(0.00381)	1.535***	(0.00401)	1.899***	(0.00353)	1.576***	(0.0258)	1.885***	(0.0126)
Observations	5,460		5,460		4,909		4,909		4,344		4,344		5,460		5,460	

Source: Authors' own elaboration. Note: Robust standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Year, region and NACE 2 digits dummy are included in the model but not reported.

Main conclusion:

- Growth rate of competition level: positive and linear effect on TFP

5. Results | Productivity

Table 5. Results of panel regression model: Productivity function (Log LP), all sectors

Variables	Random effects Model 18		Fixed effects Model 19		Random effects Model 20		Fixed effects Model 21		Random effects Model 22		Fixed effects Model 23	
Log (Competition level)	-3.147***	(0.804)	-3.092***	(0.840)	-		-		-		-	
Δ Log (Competition level) in "T"	-		-		-1.432**	(0.590)	-1.511**	(0.595)	-		-	
Δ Log (Competition level) in "T-1"	-		-		-		-		-0.475	(0.332)	-0.456	(0.328)
Constant	2.506***	(0.193)	3.256***	(0.0696)	3.338***	(0.0370)	3.510***	(0.0197)	3.687***	(0.0207)	3.496***	(0.0191)
Observations	4,987		4,987		4,466		4,466		3,939		3,939	

Source: Authors' own elaboration. Note: Robust standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Year, region and NACE 2 digits dummy are included in the model but not reported.

Main conclusions:

- Competition level: negative and linear effect on LP

- Growth rate of competition level: negative and linear effect on LP

5. Results │Productivity

Table 6. Results of log-log fixed-effect regression: TFP and LP

Variables	Model 24 - Log (TFP)		Model 25 - Log (LP)	
Δ Log (competition level) in "T"	-		-1.361**	(0.598)
Δ Log (competition level) in "T-1"	0.114***	(0.0405)	-	
Micro sized-firm	-0.300***	(0.0282)	0.430***	(0.136)
Small sized-firm	-0.147***	(0.0221)	0.126	(0.0992)
Medium sized-firm	-0.0735***	(0.0160)	0.0771	(0.0713)
Log (average salary per employee) in "T"	-0.0119	(0.0168)	0.673***	(0.136)
Received national public support for RDI in "T"	0.00584**	(0.00271)	0.0573***	(0.0188)
Patent stock per employee in "T-1"	-0.0170***	(0.00485)	0.0308	(0.0971)
Log (physical capital per employee) in "T-1"	0.0189***	(0.00429)	0.0412	(0.0265)

Source: Authors' own elaboration.

Note: Robust standard errors in parentheses. Significance level: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

N° observations: Model 7 = 4,211 | Model 9 = 4,379. R-Squared (overall): Model 7 = 0.8205 | Model 9 = 0.3669

Constant and year dummy included in the model, but not reported.

Main conclusions:

- Growth rate of competition: positive effect on TFP and negative effect on LP

- Competition effect on TFP is not immediate

- Positive effect: public support to RDI (LP and TFP), investment (TFP), qualification HR (LP)

- Negative effect: Patent Stock (TFP)

- Firm size: negative effect on LP and positive effect on TFP

5. Results | Complementary analysis

- Analysis only with firms in manufacturing industry:

    □ Positive and linear effect on innovation, in line with Correa and Ornaghi (2014)

    □ Negative and linear effect on LP

    □ No significant effect was found on TFP

- Robustness test

    □ Negative binomial regression for patent function: same results

6. Discussion and conclusion

- **Competition effect on Innovation**

  - All sectors: U-shaped relationship as predicted by Boone (2001)

  - Manufacturing industry: linear and positive in line with Correa and Ornaghi (2014)

- **Competition effect on Total Factor Productivity**

  - Positive effect but only with lagged one period (not immediate effect)

  - TFP is linked with technological progress, and the development and implementation of new technology which takes time → its impact was not immediate and was the result of a dynamic process

6. Discussion and conclusion

- Competition effect on Labour Productivity

  - Negative and immediate effect, both in level and growth rate

  - Possible justification:

    - Product innovation usually has no effect on LP, in fact, it is process innovation that has a positive effect

    - New product development and commercialization could have a negative on LP, because employees need time to adapt their skills for efficient production of the new goods, and during this process productivity can even fall

Thank you for your attention

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EXTRA INFORMATION

4. Methodology and conceptual framework

Table A1. Profitability index: Aghion et al. (2005) versus Correa and Ornaghi (2014)

Authors	Operating profits	Financial cost = capital stock * capital cost
Aghion et al. (2005)	Operating profits net of depreciation and provisions ➔ similar to EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) if amortization is not taken into account	▪ Capital stock = Perpetual inventory method➔ similar to tangible fixed assets with depreciation and amortization ▪ Capital cost = 8.5% ↳ Financial cost is similar to amortization cost
Correa and Ornaghi (2014)	Operating Income Before Depreciation ➔ similar to EBITDA (earnings before interest, taxes, depreciation, and amortization)	▪ Capital stock = Total Gross Property, Plant and Equipment ➔ similar to tangible fixed assets without depreciation and amortization ▪ Capital cost = 8.5% ↳ Financial cost is similar to amortization cost
Operating profits less financial cost is similar to EBIT (Earnings Before Interest and Taxes) = EBITDA less depreciation and Amortization		

Source: Authors' own elaboration based on Aghion et al. (2005) and Correa and Ornaghi (2014).

5. Results | Descriptive Statistics

Table A2. Productivity versus competition, by main economic activity

SECTION	Competition level		TFP		LP	
	Average	Ranking	Average	Ranking	Average	Ranking
C. Manufacturing industry	0.9374	2	7.14	3	37	6
F. Construction	0.9337	3	7.00	4	33	7
G. Trade, repair of automobiles and motorcycles	0.9470	1	7.29	2	200	2
J. Information and communication	0.9043	5	6.24	5	38	5
M. Specialized, scientific and technical activities	0.8868	6	5.45	7	99	3
N. Administrative and support services activities	0.9117	4	5.98	6	45	4
Other sectors	0.8554	7	8.77	1	759	1

Source: Authors' own elaboration based on AMADEUS database.
Note: Other sectors included firms in the following sections: A. Agriculture, Forestry and Fishing; B. Extractive industries; D. Production and distribution of electricity, gas, steam and air conditioning; E. Production and distribution of water, sanitation, waste management and depollution; H. Transport and storage; I. Accommodation and restoration; K. Financial and insurance activities; L. Real estate activities; P. Teaching; Q. Human health and social action
TFP = Total Factor Productivity. LP = Labour productivity = valued added by employee.

Main conclusions:

- Relationship between competition and productivity: positive or negative relationship depending on the economic activity and on the indicator used
  - Sectors with a high level of competition have high performance in TFP and a low performance in LP (section C and F)
  - Sectors with a high level of competition are associated with high (section G) or modest (section J) performance
  - Sectors with low (section M) or modest (section N) competition are linked with low performance in TFP and modest performance in LP

5. Results | Descriptive Statistics

Table A3. Patent versus competition level, by main economic activity

SECTION	N. Firms		Competition level		N° Patent		Patent by firm	
	Total	% Total	Average	Ranking	Total	% Total	Average	Ranking
C. Manufacturing industry	429	65.6%	0.9374	2	1 902	67.3%	4.4	3
F. Construction	22	3.4%	0.9337	3	41	1.5%	1.9	7
G. Trade, repair of automobiles and motorcycles	26	4.0%	0.9470	1	80	2.8%	3.1	4
J. Information and communication	41	6.3%	0.9043	5	112	4.0%	2.7	5
M. Specialized, scientific and technical activities	96	14.7%	0.8868	6	543	19.2%	5.7	1
N. Administrative and support services activities	18	2.8%	0.9117	4	97	3.4%	5.4	2
Other sectors	22	3.4%	0.8554	7	52	1.8%	2.4	6
TOTAL	654				2 827		4.3	

Source: Authors' own elaboration based on AMADEUS database.

Note: Other sectors included firms in the following sections: A. Agriculture, Forestry and Fishing; B. Extractive industries; D. Production and distribution of electricity, gas, steam and air conditioning; E. Production and distribution of water, sanitation, waste management and depollution; H. Transport and storage; I. Accommodation and restoration; K. Financial and insurance activities; L. Real estate activities; P. Teaching and; Q. Human health and social action

Main conclusions:

- Main sectors (86.5%): manufacturing industry (66%) and specialized, scientific and technical activities (15%)

- On average firms submitted 4.3 patents applications

- Higher level of competition: trade and manufacturing

- Low level of competition: services sectors

- Relationship between competition and innovation: positive or negative relationship depending on the economic activity.
  - Manufacturing industry: high degree of competition and high innovation performance
  - Specialized, scientific and technical activities: low competition and the highest innovation performance

5. Results | Innovation — Patent application

Table A4. Results of Poisson regression: N° of patent applications (<u>manufacturing industry</u>)

Variables	Random effects		Fixed effects		Random effects		Fixed effects		Random effects		Fixed effects	
	Model A1		Model A2		Model A3		Model A4		Model A5		Model A6	
Competition level	9.725**	(4.426)	9.999**	(4.575)	-		-		66.62	(161.0)	55.63	(164.0)
Competition level (squared)	-		-		-		-		-30.70	(87.16)	-24.63	(88.75)
Δ Competition level (Growth rate)	-		-		5.867+	(3.884)	6.012+	(3.919)	-		-	
Constant	-8.980**	(3.675)	-		0.412	(0.803)			-35.33	(74.48)	-	
Observations	3,861		2,286		3,432		1,864		3,861		2,286	
Number of id	429		254		429		233		429		254	
Log pseudolikelihood	-2 899.36		-2 009.45		-2 508.80		-1 671.80		-2 899.00		-2 009.23	

Source: Authors' own elaboration.
Note: Robust standard errors in parentheses. Significance level: $+p<0.15$; *** $p<0.01$, ** $p<0.05$, * $p<0.1$. When fixed-effects model is reported it refers to conditional fixed-effects.
Year, region and NACE 2 digits dummy are included in the model but not reported.

Main conclusions:

- Competition level: positive and linear relationship effect on innovation, as predicted by Arrow (1962)

- Growth rate of competition level: positive and linear effect on innovation