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Abstract: Innovation is one of the main determinants to stimulate productivity. However, incentives to innovate may be affected by the level of competition. In particular, in developing countries, where informality is highly prevalent, formal firms have to face both types of competition: formal and informal. Previous studies have acknowledged a negative impact from competition (*schumpeterian effect*) but also, several recent studies have shown that competition could spur innovation (*escape-competition effect*). Given the importance of informal competition in developing countries, as Peru, where almost three out of four firms are informal and the intensity of investment in R&D+i activities is pretty low, this study aims to evaluate the impact of formal and informal competition, at the industrial level, on the whole innovation process and, expressly, on productivity for Peru. By using a CDM model, this study analyses how the intensity of formal and informal competition affects every stage of the innovation process. The CDM model makes possible to study four interrelated stages of the innovation process: i) the firms' choice to engage with innovation, ii) the amount of resources invested in R&D+i activities, iii) the effects of R&D+i investments on innovation output, and iv) the impacts of innovation outcome on firms' productivity. The model is estimated using firm-level data collected by the Peruvian National Innovation Survey 2018 and the National Business Survey 2018. Our main findings indicate that competition, both formal and informal, affects negatively the decision to engage in innovation. However, the relationship changes throughout the remaining stages of the innovation process. Whereas the informal competition affects negatively the whole innovation process (engage in innovation, intensity of R&D+I activities spending, innovation output and firms' productivity) satisfying the *Schumpeterian theory*; formal competition seems to affect positively the intensity of R&D+i activities spending and also firms' productivity, which can be explained as an *escape-competition effect* within the formal firms. In conclusion, meanwhile it is found that informal competition affects negatively the whole innovation process, formal competition could, instead, encourage formal firms' willingness to invest more in R&D+i activities, increasing their productivity.

Keywords: competition, CDM model, informality, innovation, productivity

1. Introduction

Several empirical studies have demonstrated a positive relationship between the performance of the firm in Research and Development and Innovation (R&D+i) activities, and productivity growth (Hall, 2011; Hall and Jones, 1999; Rouvinen, 2002, Pakes and Griliches, 1980). Nevertheless, literature has emphasized that the execution of R&D+i activities and its spending intensity can be effected by the economic structure of the country.

Particularly, in developing countries, where informality tends to be highly predominant, the economy structure is fractured in two sectors: formal and informal. It means that formal firms not only have to compete with other formal firms, but also with the informal ones. Hence, the innovation process and its impacts on productivity seems to be affected by both types of competition: formal competition and informal competition.

On the one hand, literature recognizes that competition can reduce the incentives to invest in innovation by decreasing the monopoly rents of prospective innovative firms (Schumpeterian effect) but also, several recent studies have shown that competition could spur innovation given the higher returns that firms obtain by their investment given the need to differentiate their products and improve their process in a higher competitive market (escape-competition effect) (Castellacci, 2011).

Moreover, the effect of informality can be negative by diminishing the incentives to investment in innovation given the high levels of entrepreneurial risks (Harris, 2014). In particular, Heredia et al. (2017) find out that the impact of informal competition on the innovation performance of formal firms in emerging economies is negative, which can reinforce the Schumpeterian effect.

In line with that, considering that literature has not delved in the differentiated effects of both types of competition on the whole process of innovation, and expressly, on productivity and that, in Peru, almost three out of four firms are informal (INEI, 2018) and that, even when the propensity to carry out successfully R&D+i activities in the manufacturing sector is high (52.7%), the investment on R&D+i activities respect to sales are still pretty low (1.8%) (ENIM, 2018), this study attempts to delve into how the degree of competition at the industrial level, both formal and informal, can affect the whole innovation process and productivity. To assess this impact, the intensity of formal and informal competition, at the industrial level, is introduced in a CDM model (Crepon, Duguet and Mairesse, 1998) which makes possible to study four interrelated stages of the innovation process: i) the choice of a firm to engage in innovation, ii) the amount of resources to invest in R&D+I activities, iii) the effects of R&D+i investments on innovation output, and iv) the impacts of innovation outcome on firms' productivity.

This article is structure as follow, after the introduction, it is presented a brief literature review. Then, in the third section it is explained the data and methodology applied. The subsequent sections present the results and a discussion of these. The final sections contain the study's main conclusion.

2. Literature review

In order to analyse the relationship between innovation and productivity, Crépon, Duguet and Mairesse (1998) identified in the CDM model a logical framework with three principal interactions around i) the decision to invest in R&D; ii) the R&D spending and its impact on innovation output; and iii) the results of innovation and its effect on productivity. It is worthy to mention that in this study it is considered always the R&D+i activities, also called innovation activities.

In the CDM model, the firms' decision to invest in R&D is influenced, on one hand, by their specific characteristics, such as their size, sector and market share; and, on the other hand, by the business environment, such as the scientific advances and the demand of differentiated products. In that way, those innovative efforts increase the firms' knowledge capital stock and intensify their propensity to innovate through the creation of new products or the adoption of new process. Finally, this innovation output impact on firms' productivity level (see Figure N° 1) (Muinelo-Gallo, 2012).

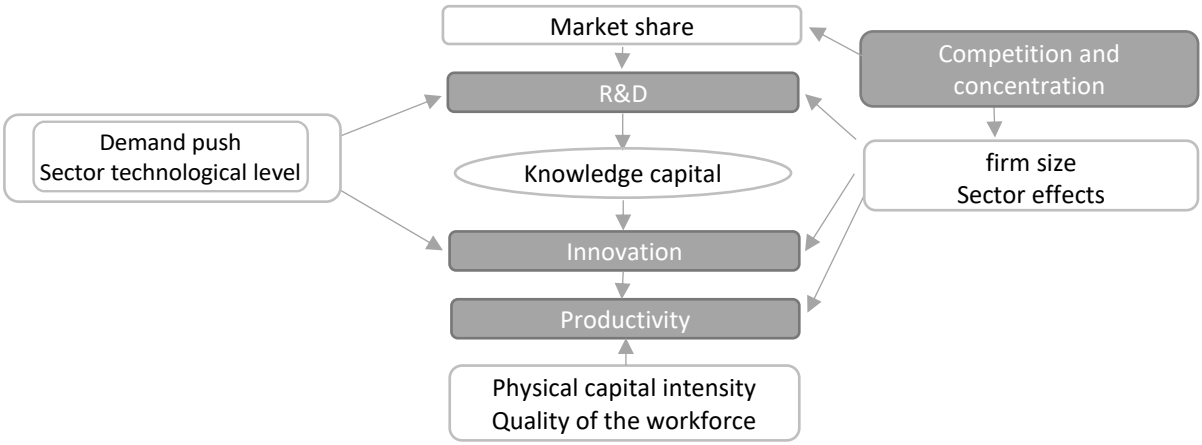

Figure 1: Logical framework of the Crépon, Duguet and Mairesse (1998) Model – CDM Model (adapted from Muinelo-Gallo, 2012)

In the CDM logical framework, the level of competition and concentration in an industry is associated with the sectorial and market share effects that influence each stage of the innovation process. In this context, the literature has shown two types of effects of the competition on innovation.

The Schumpeterian effect: On the one hand, some studies have identified that the higher competition may decrease the monopoly rents of prospective innovative firms, reducing their incentives to engage in R&D activities and innovation (Scherer, 1967; Geroski, 1990; Nickell 1996, Castellaci, 2011; Harris, 2014; Mulkay 2019). Furthermore, the literature recognized that if more monopolistic firms are more active in innovative activities because of less market uncertainty, then competitive pressure could reduce their incentives to invest

in R&D (Ahn, 2002) and to commit to innovation. Moreover, Aghion et al. (2015) point out that, in sectors that are not neck and neck, competition may discourage innovation by laggard firms when these firms do not put much weight on becoming a leader and instead mainly look at the short-run extra profit.

The Escape-competition effect: On the opposite side, some studies have shown that higher competition could also spur innovation (Aghion and Howitt, 1998). In that approach, the literature recognize that firms might innovate to survive under the competitive pressure (Porter, 1990). Furthermore, these studies explain that higher competition between companies with "neck-and-neck" technologies increases their incentives to innovate to maintain technological leadership over their rivals (Ahn, 2002, Aghion et al., 2015).

In line with both effects, recent studies have evidenced the existence of an inverted-U shape relationship between the competition intensity and innovation activities (Aghion *et al*., 2005). In this approach, in low levels of competition, the escape-competition effect is higher and spur innovation. However, if the level of competition is too high, schumpeterian effect incentives to reduce the innovation activity. Actually the effect of competition on innovation depends on the technological state of the sector. In unlevelled sectors, the Schumpeterian effect is at work even if it does not always dominate. But in levelled (neck-and-neck) sectors, the escape-competition effect is the only effect at work. That is, more competition induces neck-and-neck firms to innovate in order to escape from a situation in which competition constrains profits (Aghion *et al*., 2015). According with recent literature, informality can affect innovation, basically, by two channels (Mendi and Costagna, 2016): i) Since the informal sector tends to required low skills, there are not incentives to encourage the accumulation of human capital, which reduce the innovation practice and ii) due to the fact that informal firms face lower entry costs than formal firms, the number of competitors is too high, which may reduce the incentives to engage in innovation.

Considering the previous theoretical findings, this study aims to evaluate how the degree of competition at the industrial level, both formal and informal, can affect the whole innovation process and productivity. We formulated the two following hypotheses:

> ***H₁:*** *Formal firms experience the Schumpeterian effect on their innovation process when they face informal competition, because it means dealing with a higher number of firms with less technological intensity.*
>
> ***H₂:*** *Formal firms experience the Escape-competition effect on their innovation process when they face formal competition, because it means dealing with fewer firms with higher technology intensity.*

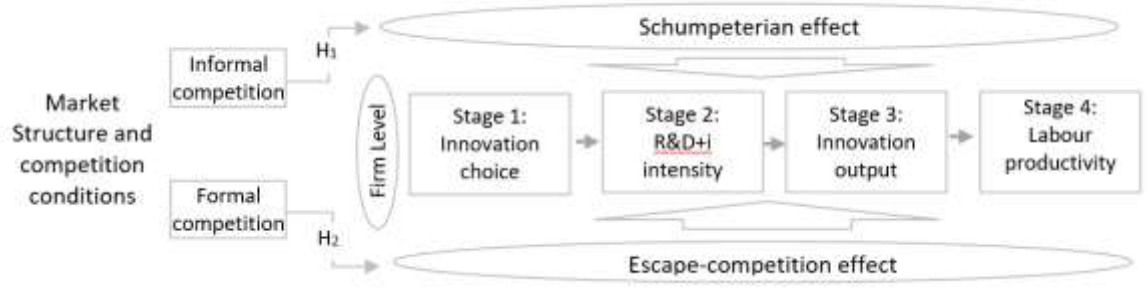

Figure 2: Model and hypotheses

3. Methodology

3.1 Database

The data used in this study came from two surveys with firm-level information: the Peruvian National Innovation Survey 2018 (ENIM) and the National Business Survey 2018 (ENE). The ENIM 2018 database is representative at the national level for manufacturing firms and contains firm level information of innovation activities for the years 2015, 2016, and 2017. The sectoral coverage of the survey was for the manufacturing industry, section C of the International Standard Industrial Classification (ISIC) (Class 1010 to 3320). A total of 1,463 manufacturing firms were interviewed, which is equivalent to 9,894 firms considering the expansion factor.

In this study, the ENIM 2018 information is utilized to identify the innovation process in manufacturing firms and additional firms' specific control characteristics. On the one hand, this database defines nine types of innovation activities: i) Internal R&D, ii) External R&D, iii) Engineering design or creative activities, iv) Marketing and brand value, v) Intellectual Property, vi) Training, vi) Development or acquisition of software, viii) Acquisition of capital goods (including hardware), and ix) Innovation Management. On the other hand, ENIM 2018 consider two types of innovation results: i) in products and ii) in business processes. Likewise, the ENE 2018 database is representative at ISIC-2 digits industrial level. In this study, this source of information is used to identify the level of formal and informal competition at the industrial level. Thereby, the intensity of formal (informal) competition in an industry is defined as the proportion of firms that reported that formal (informal) competition as a relevant obstacle to continue operating.

3.2 CDM model with formal and informal competition

This study is focused on evaluating the impact of formal and informal competition on the whole process of innovation by using a CDM Model. Thus, the model is characterized in four equations that represents i) the firm's decision to invest in innovation activities, ii) the intensity of investment in innovation activities, iii) the knowledge production function (innovation outcome), and iv) the production function (labour productivity transformed by logarithms). Additionally, the formal and informal competition intensity variable are introduced in every function.

The CDM model correct the problem of selection bias and endogeneity in the innovation and productivity process. Therefore, in the first stage, the selection equation (1) describes whether the firm decides to invest in innovation.

$$ID_i = \begin{cases} 1 \; si \; ID_i^* = w_i'\alpha + \varepsilon_i > c, \\ 0 \; si \; ID_i^* = w_i'\alpha + \varepsilon_i \leq c \end{cases} \quad (1)$$

In equation (1), ID_i is a binary observable variable that represents the investment decision in innovation of the firm 'i'. ID_i is equal to one if the firm invests in innovation activities, and equal to zero otherwise. Likewise, ID_i^* is a latent variable that reveal the preferences of investment decision in innovation of the firms. Thereby, if ID_i^* is above the threshold c, the firm would invest in innovation. Additionally, w is a vector of variables that explain the investment decision in innovation, and includes the formal and informal competition intensity variable. Finally, α is the vector of parameters of interest and ε_i is a normal distributed error term.

In equation (2), the second stage of the CDM model, IE_i is the observed intensity of investment in innovation activities. Likewise, IE_i^* is approximated by means of the logarithm of innovation activities expenditure per worker denoted by IE_i only if firms make (and report) said expenditure. Additionally, zi is a vector of independent variables that affect the effort in innovation, variables. Assuming that the error terms have zero mean, variance $\sigma_\varepsilon^2 = 1$, and correlation coefficient $\rho_{\varepsilon e}$, the system of equations (1) and (2) is estimated using a generalized Tobit model with maximum likelihood.

$$IE_i = \begin{cases} IE_i^* = z_i'\beta + \varepsilon_i \; si \; ID_i = 1 \\ 0 \; si \; D_i = 0 \end{cases} \quad (2)$$

In the third stage of the CDM model, equation (3) represents the firms' production function of innovation (or knowledge). Thereby, TI is a dummy variable that equals to one when the company has introduced an innovation, and equals to zero otherwise. Likewise, IE_i^* is the prediction of the value of the innovative effort of the company from the previously estimated generalized Tobit equations (2). Thus, x_i is a vector of input variables that affect the knowledge production, which include the formal and informal competition, u_i is an error term and F is a standard normal distribution function.

$$TI_i = F(IE_i^*\gamma + x_i'\delta + u_i) \quad (3)$$

Finally, in equation (4), firms are assumed to adopt a Cobb-Douglas function with constant returns to scale. This function includes the y_i is the firm's labour productivity as dependent variable, and capital per capita (k) and the knowledge input (TI*) estimated in equation (3) as independent variables.

$$y_i = \pi_i k_i + \pi_2 TI_i + v_i \qquad (4)$$

In this study, y_i is the logarithm of sales per worker in the last year of the survey. Similarly, k_i is the logarithm of physical capital per worker in the initial year, and TI_i is the prediction of the knowledge production function and captures the impact of innovation on productivity levels. In addition to these variables, following the studies reviewed, the estimated model incorporates a vector with additional control variables to equation (4), which include the formal and informal competition intensity.

4. Results

4.1 Descriptive statistics: Innovative firms and competition intensity

In Peruvian manufacturing (2015-2017), around 52.7% of companies are innovative firms but the intensity of the investment on innovation activities are still pretty low (ENIM, 2018). On the one hand, the manufacture of petroleum (83.0%), pharmaceuticals (74.4%) and machinery and equipment (73.9%) are the industries with the highest percentage of innovative firms which exceed three-quarters of each industry. On the other hand, the manufacture of non-metallic minerals (4.7%), pharmaceutical products (4.2%) and production of wood (3.8%) are the industries with the highest intensity in investment in innovation activities, but that represents less than 5% of their sales.

Table 1: Innovative behaviour, competition and labour productivity according to manufacturing activity 2018

Div.	Manufacturing sector	Percentage of innovative firms	Investment intensity in innovation activities a/	Labour productivity b/		Informal competition c/	Formal competition c/
10	Foods	51.9%	1.1%	11.9		56.4%	39.9%
11	Drinks	58.8%	0.9%	12.0		47.5%	36.1%
13	Textiles	36.1%	0.7%	11.8		60.7%	43.0%
14	Clothing	48.7%	0.7%	12.0		55.6%	29.3%
15	Leather and related products	65.3%	0.7%	12.0		53.8%	17.3%
16	Wood and derivatives	44.9%	3.8%	11.9		66.0%	32.4%
17	Paper	71.3%	2.0%	11.8		56.9%	50.0%
18	Editing, printing, and recording	42.6%	1.3%	11.8		60.8%	46.6%
19	Petroleum products	83.0%	3.1%	14.1		41.3%	11.4%
20	Chemical substances and products	55.6%	1.6%	12.4		42.9%	41.0%
21	Pharmaceutical products	74.4%	4.2%	12.4		14.8%	44.5%
22	Rubber and plastic	58.6%	2.5%	12.2		52.8%	52.6%
23	Other non-metallic mineral products	49.4%	4.7%	12.0		59.9%	36.5%
24	Common metals	67.4%	0.2%	12.1		44.4%	32.3%
25	Metal products	48.4%	1.7%	11.6		58.2%	28.3%
26	Computer Products	54.0%	1.6%	11.9		27.7%	19.9%
27	Electric equipment	49.6%	0.8%	12.0		50.8%	38.9%
28	Machinery and equipment	73.9%	2.1%	11.7		43.3%	19.2%
29	Motor vehicles	48.7%	1.3%	12.2		63.0%	20.7%
30	Other transport equipment	67.0%	2.7%	12.6		57.5%	27.2%
31	Furniture	65.0%	0.4%	11.6		47.6%	32.3%
32	Other manufacturing industries	65.6%	1.4%	11.8		47.6%	36.9%
33	Machinery and equipment repair	52.7%	3.1%	11.5		55.9%	34.2%
	Total	**52.7%**	**1.8%**	**12.1**		**50.7%**	**33.5%**

a/ The intensity of the investment in innovation activities was obtained by dividing the total spending on these activities, for the period 2015-2017, by the total sales for the same period. The universe considered was the total of manufacturing companies that invested in innovation activities.
b/ Labour productivity is calculated as the logarithm of the following division: sales over the number of workers for the year 2017.
c/ The intensity of competition was calculated by the number of firms in an industry reporting that competition is a relevant obstacle (informal or formal) divided by the total number of firms in the industry.

In Peru, the intensity of informal competition (50.7%) in manufacturing is higher than formal competition (33.5%). The intensity of formal (informal) competition in an industry is defined as the proportion of firms that

reported that formal (informal) competition is a relevant obstacle to continue operating. The economic sectors with the highest intensity of informal competition are those related to motor vehicles, leather products, and wood and derivatives. On the contrary, the pharmaceutical products industry presents a greater intensity of formal competition. Finally, highest labour productivity are the ones related to petroleum products, transport equipment and pharmaceuticals products.

4.2 CDM model results

In table 2, the results reveal a significant and negative marginal effect of formal and informal competition on the probability of investing in innovation activities in the Peruvian industry. Thereby, this estimation satisfies the *schumpeterian effect* hypothesis, meaning that the higher level of competition, the lower the probability of investing in innovation activities.

Table 2: Effect of informal and formal competition on the probability of investing in innovation activities

Dependent variable	**Probability of investing in innovation activities**
Informal competition	**-0.0065*** **
Formal competition	**-0.0048** **
Percentage of qualified employees	0.2221*
Links with research centres / universities	0.5777***
Linking with competitors	0.5574***
Link with technical centres	0.4751***
*** p<0.01, ** p<0.05, * p<0.1	

In table 3, the results reveal a differentiated effect of formal and informal competition on innovative effort. On the one hand, this estimation recognizes that informal competition affects negatively the intensity of investment in innovation activities (*schumpeterian effect*). On the other hand, the formal competition exhibits a positive and significantly effect to the innovative effort (*escape-competition effect*).

Table 3: Effect of informal and formal competition on innovative effort (intensity of investment in innovation activities)

Dependent variable	**Innovative effort (intensity of investment in innovation activities)**
Informal competition	**-0.022***
Formal competition	**0.024***
Percentage of qualified employees	1.917***
Holding of intellectual property rights	0.776**
Chains with extractive sectors	0.868***
*** p<0.01, ** p<0.05, * p<0.1	

In table 4, the results reveal a significant negative direct effect of formal competition on the probability of obtaining innovation outcome (*schumpeterian effect*). Likewise, the magnitude of the innovative effort, the access to public financing and the size of the firm, associated with the number of workers, significantly increase the probability of achieving an innovative result.

Table 4: Effect of informal and formal competition on the probability of obtaining innovation outcome

Dependent variable	**Get innovation results Dichotomous variable (1=innovative firm)**
Informal competition	**-0.0011**
Formal competition	**-0.0075*** **
Number of employees (Log)	0.0725***
Access to public financing	0.5009***
Innovative effort (intensity)	0.1775***
*** p<0.01, ** p<0.05, * p<0.1	

In table 5, it is possible to observe that, for the period 2015-2017, considering the effects of competition, innovation and productivity are associated positively. In average, innovation increases in 20.8% - 24.7% labour productivity. This result is in the range of the values reported in the study by Crespi and Zuñiga (2010), identifying the following: Argentina (24%), Chile (60%), Colombia (192%), Panama (165%), and Uruguay (8%).

Otherwise, the results are not entirely conclusive and significant about the direct effect of competition on labour productivity. However, the econometric estimations allow to conjecture that informal competition has a negative impact on labour productivity; meanwhile, formal competition seems to have a positive effect. Indeed, Amin *et. al.* (2019) reported that labour productivity of formal firms that face competition from informal firms is about 75% of the average labour productivity of formal firms that not experience informal competition.

Table 5: Effect of the innovation and the informal and formal competition on labour productivity

Dependent variable	**Labour productivity (1)**	**Labour productivity (2)**	**Labour productivity (3)**	**Labour productivity (4)**
Informal competition	-0.011**	-0.011*	-0.005	-0.007
Formal competition	0.007	0.008*	0.004	0.003
Innovative effort prediction (intensity)			0.208**	0.247***
Introduction of innovation prediction		0.153		-0.287
*** p<0.01, ** p<0.05, * p<0.1				

5. Conclusion

This study was conducted to evaluate how the intensity of formal and informal competition affects every stage of the innovation process. By using a CDM model, the intensity of informal and formal competition, at the industrial level was introduced in every equation representing each stage of the innovation process. Following the provided literature, two hypotheses were tested: i) Formal firms experience the Schumpeterian effect on their innovation process when they face informal competition, because it means dealing with a higher number of firms with less technological intensity and ii) Formal firms experience the Escape-competition effect on their innovation process when they face formal competition, because it means dealing with fewer firms with higher technology intensity.

It is notable that informal competition in the manufacturing sector is more intense than formal competition, on average. Aghion *et al*. (2005) already manifested that the higher number of informal firms with less technological intensity could explain why informal competition does negatively affect the entire innovation process.

Results show that informal competition has a negative effect in the whole innovation process for the manufacturing sector in Peru, that is to say informal competition discourage formal firms to engage with innovation, to invest in R&D+i activities; and as a result, innovation output is null or low that affects negatively firms' productivity. Those findings satisfy the Schumpeterian theory, allowing us to guess that informal competition reinforce the negative effects of competition given the with a higher number of firms with less technological intensity.

Meanwhile, formal competition seems to have a positive impact in the firms' willingness to invest in R&D+i activities and it is associated positively with labour productivity. That result can be explained as an escape-competition effect within the formal firms. Even when the number of formal firms tend to be fewer, the investment intensity in higher technology seems to be greater, which incentives other formal firms to level innovation in order to not lose market share.

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