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Innovation, market power and biotechnology in the Brazilian Chemical industry

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Abstract

The aim of this paper is to analyze ex-ante (market share) and ex-post (appropriability) market power and the impact of biotechnology on Brazilian Chemical industry firms' innovation and R&D decisions using microdata from Brazilian innovation surveys. The same study was carried out on firms from the general manufacturing industry and used as a benchmark. This kind of research is particularly important given that innovation and biotechnology are on government and industry agendas. The descriptive results show that chemical industry firms on average use more biotechnology, are more innovative, use more appropriability mechanisms and have a larger market share than manufacturing industry firms. Regression analysis results suggest that ex-ante and ex-post market power have a positive impact on decisions made by manufacturing and chemical industry firms in terms of both R&D and innovation. Biotechnology has an overall positive impact on all manufacturing industrial firms R&D and innovative activity. Regarding chemical industry firms, the positive impact is only noted on continuous R&D. This suggests that biotechnology in the chemical industry is a specific innovative effort that can spread throughout the whole industry since chemistry is part of all products and production processes. Considering the industry as a whole, biotechnology is most likely only viewed as a production and processing alternative. Despite this, the albeit limited use impacts the whole industry.

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1. Introduction

Innovation is a key variable in any modern economy and is fundamental to understanding the innovative process, particularly its inputs and outputs. The chemical industry is a distinct sector as its products are directly and indirectly part of the lives of consumers and firms as well as being one of the most innovative industries in the USA and Europe. As illustrated in the former Journal of the Society of Chemical Industry (1882-1950), biotechnology and chemistry came together some time ago. This was followed by the Journal of Applied Chemistry (1951-1970) and more recently in 1971, in the Journal of Chemical Technology and Biotechnology. Since 1978, the European Federation of Biotechnology has paid particular attention to chemical and biotechnology interaction, including industry application. Biotechnology was in fact presented as a feasible alternative in the chemical industry, particularly in the production and processing of chemicals for sustainable development.

In this context, the aim of this paper is to analyze ex-ante (market share) and ex-post (appropriability) market power and the impact of biotechnology on Brazilian Chemical industry firms' innovation (product and process) and R&D (internal, external, continuous) decisions using microdata from Brazilian innovation surveys. The same study was carried out on firms from the general manufacturing industry and used as a benchmark.

Descriptive results show that firms in the chemical industry on average use more biotechnology, are more innovative, use more appropriability mechanisms and have greater market share SIC 3 digit than manufacturing industry firms. Regression analysis results suggest that ex-ante and ex-post market power have a positive impact on decisions made by firms in the manufacturing and chemical industries regarding both R&D and innovation. Biotechnology, however, has an overall positive impact on all manufacturing industrial firms' R&D and innovative activity. Regarding chemical industry firms, positive impacts can only be noted on continuous R&D. This finding suggests that biotechnology in the chemical industry is a specific innovative effort that can be spread throughout the whole industry since chemistry is part of all products and production processes. Considering the industry as a whole, biotechnology is most likely only viewed as a production and processing alternative. Despite this, the albeit limited use impacts the whole industry.

Following this introduction, a short revision of the related literature, the database, variables and results and final comments will be presented.

2. Related literature

The importance of chemistry in everyday life is clear. Basically speaking, all products and production processes contain some chemical component. However, even though the it appears on research agendas, as shown by Human Genome and Encode Projects, and features in journals dedicated to biotech – such as Biotechnology Advances and Trends in Biotechnology (both since 1983) - the importance of biotechnology on the lives of consumers and firms is less clear.

The last half century of empirical studies on innovative activity and performance was summed up by Cohen (2010). From his review of the "neo-Schumpterian" empirical

studies about firm size, market concentration and appropriability upon innovation we highlight: i) the U-shape relation between market concentration: very large firms displaying relatively high R&D productivity, ii) that there are two market power effects: ex ante, due to market concentration and ex post, due to the use of appropriability mechanisms, iii) that causality could be from market structure to innovation (our hypothesis) or the opposite, from innovation to market structure, iv) that the relationship is sensitive to industry level factors – which we try to highlight by comparing the performance of chemical firms with all manufacturing companies, v) non-observable firm specific characteristics and the role of unobservable firm heterogeneity matters – which we try to get through probit panel regression random effects and vi) that appropriability conditions vary a great deal among sectors and countries.

Cohen, Nelson, Walsh (2000) provided crucial details about the use of appropriability mechanisms. They found that firms typically protect profits via innovation with a range of mechanisms, including patents, secrecy, lead time advantages and the use of complementary marketing and manufacturing capabilities. Of these mechanisms, however, patents tend to be the least emphasized by firms in the majority of manufacturing industries. In fact, firms use a mix of appropriability mechanisms as opposed to patents alone.

Survey-led approaches have transformed our understanding of the nature and determinants of innovation (Hong, Oxley and McCann, 2012). Considering the current decade, it is clear that without comprehensive data and testing, the debate on innovation determinants and impacts cannot be satisfactorily resolved either way. Concerns surrounding data quality and data access should at least be considered, given that the micro innovation data administrated by the state is often considered to be highly confidential. The results of the present research are closely in line with these findings.

Innovation and biotechnology are high priorities of government and business in Brazil, as can be seen in official public documents. The Brazilian Federal Government has carried out many initiatives to improve innovation in the last two decades.

For example, firm-level microdata according to European Community Innovation Survey (CIS) standards which is fundamental to understanding innovation (HONG, OXLEY, McCANN, 2012). Since 2000 the Brazilian Innovation Survey (Pintec) by the Brazilian Census Bureau (IBGE) has provided microdata on R&D and the innovative performance of Brazilian manufacturing firms.

Brazilian Government also introduced funds such as the National Scientific and Technological Fund (FNDCT), since 1969, which has had a positive impact on firms' R&D performance (De NEGRI, De NEGRI, LEMOS, 2008), and many financial innovation funds managed by the Brazilian Project Finance Agency (Finep) and the Social Economic National Development Bank (BNDES). New laws was sanctioned such as Law 10.973, which since December 2004, has offered legal support to firm-university strategic partnerships, has provided incentive to science and technological institutes to be part of innovation process and incentive to initiate innovations in firms, and Law 13.243, which provides incentive to scientific development, and R&D and innovation support, valid since January 2016. At least, The Brazilian National Science, Technology and Innovation Strategy 2016-2019 established "biome and bioeconomy" as a strategic subject and recognizes that the best way to overcome water and food

challenges is via biotechnology, and Brazilian Industry, through the National Industry Confederation (CNI), which has been working on a Bioeconomy Agenda since 2013.

3. Data base, variables and results

The Brazilian Innovation Survey (Pintec) is conducted by the Brazilian Census Bureau (IBGE), a Federal Government agency, and provides a broad micro database on innovation at firm level according to European Community Innovation Survey (CIS) standards. As with much of the innovation microdata, Pintec is administrated by the state and because of strong census confidentiality its access is restricted. In 2017, Pintec released editions from the years 2000, 2003, 2005, 2008, 2011 and 2014. Information about appropriability is available in the 2003, 2005, 2008 editions and about biotechnology in the 2005, 2008, 2011, 2014 editions. Both types of information are only found in the 2005 and 2008 editions.

Our unbalanced panel of microdata from the 2005 and 2008 Pintec editions has 828 firms from the chemical sector, 14,577 firms from industry manufacturing and information about R&D (internal, external, continuous), innovation (product and process), appropriability mechanisms (patents and trademarks, among others), use of biotechnology and net revenue (which allow us to calculate market share).

3.1 Regression structure

The following PROBIT panel data regression model is proposed:

$$INOVA_{litj}=\beta_0+ \beta_1 MS_{itj}+\beta_2 MS^2_{itj}+\beta_3 BIOTEC_{it}+\beta_4 PAT_{it}+\beta_5 TRADE_{it}+RE_{it}+\varepsilon_{it} \quad (1A)$$

$INOVA_{litj}$ is a dichotomous variable and can be both an R&D (internal or external or continuous) or an innovation (product or process innovation) output. It is 1 if the firm i at period t in SIC3 sector j worked on innovative action, and 0 otherwise. MS_{itj} is continuous and means firm i at period t in SIC3 sector j market share. MS^2_{itj} is MS_{itj} square and helps us check the traditional U-relation between innovation and market structure. $BIOTEC_{it}$ is a binary variable, and is 1 if the firm uses biotechnology, 0 otherwise. PAT_{it} and $TRADE_{it}$ are also dichotomous when using patents of invention and trademarks, respectively. Patents because they are the most traditional appropriability mechanisms and trademarks because they are at the core of all companies. RE_{it} represent random effects and supposedly capture non-observable firms' specific heterogeneous characteristics, and ε_{it} is the error term with standard hypothesis: mean zero and finite variance.

It is rational to use not only patents and trademarks but also a mix of appropriability mechanisms (MAM[1]) as evidence presented by Cohen, Nelson and Walsh (2000) suggests. This fact was considered in the second version of our regression:

[1] Pintec ask companies about the possible use of eight appropriability mechanism options: invention patents and trademarks, utility model patents, industry designs, copyright, designing complexity, industrial secrets and competitive lead times. We create a MAM for the simultaneous use of at least two of those eight Pintec options. For example, the MAM could be patents and trademarks or industry design, industrial secrets and competitive lead times, and so on.

$$INOVA_{litj} = \beta_0 + \beta_1 MS_{itj} + \beta_2 MS^2_{itj} + \beta_3 BIOTEC_{it} + \beta_4 MAM_{it} + RE_{it} + \varepsilon_{it} \quad (1B)$$

3.2 Regression analysis results and comments

The PROBIT panel regression results for firms in the Brazilian chemical industry come from equation 1A and can be seen in Table 1A. Market share has a positive impact on all R&D, but only on product and not process innovation. This suggests that the firm size effect is present but is not the same in all innovative activities. Market share squared only has a negative impact on external and continuous R&D. This means a U-shape relation between R&D and firm size is present in these cases. Biotechnology only improves continuous R&D activity. Patents and trademarks positively affect almost all active innovation, except internal R&D (patents) and process innovation (trademarks). It is important to note that trademarks and advertising always work together since the main objective of advertising expenditure is to disseminate or strengthen the trademark. Continuous R&D stands out as the only innovative activity which biotechnology, conditional to ex-ante and ex-post market power, has a positive impact on.

Table 1B sums up the results of equation 1B. In general, the results are similar to those presented above, aside from the significantly positive impact of market share on process innovation and the negative impact of the square of market share on internal R&D. In analyzing the details, it can be seen that market share and its square keep the sign and significance, as does biotechnology, which suggests that firm size and biotech are not adequate appropriability mechanisms. A mix of appropriability mechanisms (MAM), however, improves Brazilian chemical industry firms' R&D and innovation probability activity, except with regards to process innovation. This shows that these firms utilize a combination of appropriability options - which is fully rational according to Cohen, Nelson, Walsh (2000). It is important to note that according to Cohen (2010), market share and MAM are, respectively, ex-ante and ex-post market power sources. Thus, these results reveal that market power improves firms' R&D and innovation in the Brazilian chemical industry.

Regarding the PROBIT panel regression results for Brazilian manufacturing industry firms, table 2A shows the results for equation 1A and Table 2B for equation 1B. The result is basically the same for both. Market share has a positive impact on all R&D and innovative activity but has a greater impact on R&D than on innovation. Again, this suggests that the firm size effect is always present but of unequal dimensions according to the innovative activity. Market share squared has a negative impact on all types of R&D and innovative activity which means there is a general U-shape relation between R&D or innovation and firm size. Biotechnology has a general positive impact on all R&D and innovative activity, to a slightly greater extent on continuous R&D. Considering appropriability options, patents improve all R&D activity and product innovation but do not improve process innovation. This result is similar to the impact on trademarks. The result is quite similar to MAM, which suggests that firms in the industry as a whole not only mix up appropriability mechanisms but also pay particular importance to classical knowledge industry protection such as patents and trademarks.

TABLE 1A – R&D, innovation and market structure - Brazilian chemical industry

		Internal R&D	External R&D	Continous R&D	Product Innovation	Process Innovation
β_0	CONSTANT	-0.26*	-1.66*	-0.90*	0.54*	0.62*
β_1	MS	20.27*	18.73*	26.92*	6.77*	3.64
β_2	MS^2	-33.79	-56.66*	-53.04*	-16.19	-8.98
β_3	BIOTEC	0.38	0.22	0.46***	0.09	0.28*
β_4	PATENTS	0.30	0.43*	0.57*	0.41**	0.21*
β_5	TRADEMARK	0.43*	0.26**	0.25***	0.70*	-0.20**
	Log likelihood	-515.71	-302.46	-508.78	-404.24	-471.99

Source: authors calculations from Pintec's microdata in the 2005 and 2008 editions.
Each regression has 828 observations. *,**,*** means, respectively, 1%, 5%, 10% significance level.

TABLE 1B – R&D, innovation and market structure - Brazilian chemical industry

		Internal R&D	External R&D	Continous R&D	Product Innovation	Process Innovation
β_0	CONSTANT	-0.33*	-1.69*	-1,06*	0.47*	0.58*
β_1	MS	21.04*	20.89*	28.99*	7.06*	4.32***
β_2	MS^2	-35.63***	-63.08*	-57.23*	-16.13	-10.86
β_3	BIOTEC	0.41	0.29	0.51***	0.128	0.29*
β_4	MAM	0.51*	0.34**	0.55*	0.71*	-0.05
	Log likelihood	-515.71	-306.93	-500.89	-406.73	-474.92

Source: authors calculations from Pintec's microdata in the 2005 and 2008 editions.
Each regression has 828 observations. *,**,*** means, respectively, 1%, 5%, 10% significance level.

TABLE 2A– R&D, innovation and market structure - Brazilian manufacturing industry

		Internal R&D	External R&D	Continous R&D	Product Innovation	Process Innovation
β_0	CONSTANT	-1.32*	-1.96*	-2.04*	0.07*	0.84*
β_1	MS	15.80*	9.59*	16.05*	5.21*	2.91*
β_2	MS^2	-17.26*	-9.93*	-17.05*	-6.09*	-2.99*
β_3	BIOTEC	0.53*	0.44*	0.70*	0.18*	0.24*
β_4	PATENTS	0.88*	0.45*	1.05*	0.74*	0.035
β_5	TRADEMARK	0.51*	0.36*	0.62*	0.49*	-0.22*
	Log likelihood	-7966.37	-4208.01	-6457.29	-9156.47	-7779.88

Source: authors calculations from Pintec's microdata in the 2005 and 2008 editions.
Each regression has 14,577 observations. *,**,*** means, respectively, 1%, 5%, 10% significance level.

TABLE 2B – R&D, innovation and market structure - Brazilian manufacturing industry

		Internal R&D	External R&D	Continuous R&D	Product Innovation	Process Innovation
β_0	CONSTANT	-1.45*	-2.07*	-2.25*	-0.01	0.85*
β_1	MS	16.58*	10.03*	17.08*	5.74*	3.09*
β_2	MS^2	-18.10*	-10.38*	-18.11*	-6.56*	-3.24*
β_3	BIOTEC	0.54*	0.46*	0.73*	0.19*	0.24*
β_4	MAM	0.80*	0.56*	1.02*	0.68*	-0.18*
	Log likelihood	-7981.18	-4200.64	-6475.97	-9147.81	-7789.79

Source: authors calculations from Pintec's microdata in the 2005 and 2008 editions.
Each regression has 14,577 observations. *,**,*** means, respectively, 1%, 5%, 10% significance level.

4. Final comments

The two forms of market power (ex-ante and ex-post) have heterogeneous effects on innovation outcomes. In particular, the impact of appropriability (or ex-post market power) on R&D or innovation is smaller among Brazilian chemical firms than among Brazilian manufacturing firms, as well market share (or ex-ante market power). A u-shape relation between R&D or innovation and firm size is always present. Biotech, however, has a general positive impact on all manufacturing industry firms' R&D and innovative activity but a positive impact on only chemical industry firms' continuous R&D. This suggests that biotech in the chemical industry is a specific innovative effort that can be spread throughout the whole industry since chemistry is part of all products and production process. Considering the industry as a whole, biotechnology is most likely only viewed as a production and processing alternative. Despite this, the albeit limited use impacts the whole industry.

These results are important given that the chemical industry is a key sector in a global and innovative economy, and innovation policy appears to be more important than industrial policy, as recent USA (2011) official documents highlight. In addition, biotechnology is not only on academic the agenda but part of government and private sector priorities as the OECD (2009), Brazilian Innovation Strategy (2016) and CNI agenda on bioeconomy (2013) perspective points out.

Despite the importance of chemistry and biotechnology and the fact that innovation is a major priority of the government, there are few studies on the chemical sector's innovative performance. This is particularly so in recent times and in terms of testing the relation between innovation, market power and biotechnology and comparing it with the innovative performance of the manufacturing industry as in this study on Brazil using microdata.

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