Complementarity of Innovation Policies in the Brazilian Industry: An Econometric Study

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Abstract

The paper aims at assessing discrete complementarities in innovation policies in the context of the Brazilian industry in 2003. The paper considers the approach advanced by Mohnen and and Röller [*European Economic Review*, 2005] that focuses on supermodularity and submodularity tests for obstacles to innovation (in the present application: lack of finance sources, lack of skilled personnel, lack of cooperation opportunities and lack of information on technology or markets). The application avoids micro-aggregation of the data and explicitly considers sampling weights in the econometric estimation. The analysis highlights the two phases of the innovation process in terms of the propensity and intensity of innovation. The evidence, unlike previous evidence, is not totally clear cut in terms of contrasts of the two phases. Nevertheless one can detect some substitutability and complementarity for specific pairs of obstacles in analysing the propensity to innovate, and strong evidence of complementarities in obstacles when considering the intensity of innovation. In the latter case, therefore, the evidence is suggestive and favours the adoption of more targeted incentive policies.

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Keywords: supermodularity, complementarities, innovation.

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1. Introduction

The role of active innovation efforts in fostering economic growth is largely recognized in the endogenous growth literature [see e.g. Romer (1990)] and therefore highlights non-negligible challenges for developing economies to meet the technological gap. In a globalized context the competitive pressure is likely to become more important and increasingly requires the pursual of innovative activities that might require well coordinated government policies. In fact, innovation in developing countries is often incipient and not rarely important multinational firms tend to undertake R&D investments in their headquarters in other countries.

The Brazilian economy is large and shows the coexistence of technologically dynamic sectors with traditional sectors with low technological effort and constitutes an interesting case for investigating issues associated with the design of innovation policies. A handful of studies, as for example, Resende and Hasenclever (1998), De Negri et al. (2005) and Kannebley et al. (2005) pointed out the reduced technological effort that has prevailed in that economy. A natural question is to what extent active government policies can induce a significant degree of innovation by firms. Indeed, in Brazil a varied set of often uncoordinated incentive policies to innovation have been adopted and comprised special sectoral funds, favourable loans and most notably fiscal incentives policies [see Bastos (2004)].

The different forms of interrelatedness of innovation policies possess distinct policy implications. In that sense, a growing interest has emerged in connection

with the empirical assessment of complementarities in innovation policies as exemplified by Arora and Gambardella (1990), Arora (1996), Ichniowski et al., (1997) and Miravete and Pernias (2006) in terms of indirect approaches. The possibility of a given innovation activity positively affecting the return of other activities characterizes a complementarity and a direct approach in a discrete setting has been advanced by Mohnen and Röller (2005). The evidence for four European countries indicated that the prevalence of complementarities depend on the phase of the innovation process. The propensity to innovate would be better stimulated by a package of policies whereas the intensity of innovation would call for more specific targeted policies.

The aforementioned approach is promising and is here considered in the context of the Brazilian industries. The motivation for the paper builds on at least three aspects:

a) The scarcity of related works in the context of developing economies;

b) The possibility of avoiding micro-aggregation of the data and the potential related biases;

c) The consideration of estimators that acknowledge the complex sampling of the innovation survey;

The paper is organized as follows. The second section discusses some conceptual aspects associated with the assessment of complementarities in innovation policies and econometric strategies for assessing it. The third section discusses the data source, the empirical model. The fourth section presents the empirical results. The fifth section brings some final comments.

2. Complementarity in Innovation

2.1- Conceptual Aspects

The empirical assessment of complementarities in innovation activities can be object of a variety of research strategies [see Athey and Stern (1998)) for an overview]. Indirect frameworks include the "correlation approach" and the so-called "reduced form approach". The former approach emphasizes the association between different choice variables with varying degrees of theoretical foundation [see e.g. Arora and Gambardella (1990), Ichniowski et al., (1997) and Miravete and Pernias (2006)] whereas the latter focuses on exclusion restrictions and highlights similar effects of exogenous variables on complementary variables [see e.g. Holmstrom e Milgrom (1994)]

A more direct approach considers special features of an innovation function where complementarities in innovation policy would be associated to the supermodularity of that function. Examples include Mohnen and Röller (2005) and Lokshin et al. (2007). The present paper closely follows the approach advanced by the former authors. The assessment of discrete complementarities requires that one imposes a lattice ordered structure in the domain of the innovation function and evaluates the possibility of supermodularity of that function.[1] The prevalence of complementarities in innovation policies relates to situations where the whole exceeds the sum of the parts for some innovative outcome variable. Let $I(a, \theta)$ represent a general innovation function where $a = (a_1, \ldots, a_k)$ denotes a set of

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[1] Introductory overviews of the related concepts appear in Milgrom and Roberts (1995) and Vives (1999).

government policies variables and θ_l indicates other relevant control variables that might portray institutional and characteristics that can be firm or sector-specific. Supermodularity of that function would prevail if for all combinations of actions *a'* and *a''*, holds:[2]

$$I((a'\wedge a''),\theta)+I((a'\vee a''),\theta)\geq I(a',\theta)+I(a'',\theta) \quad (1)$$

The previous definition is more readily understood if one considers an example with **A**={(0,0),(1,1),(0,1),(1,0)}. Supermodularity would prevail if I(1,0)+I(0,1) ≤ I(1,1)+I(0,0) or yet I(1,0)-I(0,0) ≤ I(1,1)-I(0,1). This inequality indicates that the reward for increasing a given activity is higher when the other activity is already undertaken. The analysis becomes more complex as the number of inequalities to be considered increases with the number of available policies. A convenient result was advanced by Topkis (1978) and allows to focus on pairwise analyses as a function is supermodular over a subset of its arguments, if and only if all pairwise components in the subset satisfy the previous definition.

In the general case of k policies there will be $2^{(k-2)}\sum_{i=1}^{k-1}i$ non trivial restrictions to be tested. In particular, in the application considered by Mohnen and Röller (2005) and in the present paper there are 24 restrictions to be considered since k =4 in those cases.

In practice, the government policies are often not observed in survey data, and one might need to rely on indirect measures that indicate perceived obstacles to innovation. One would then define $C_k = -a_k$, where C_k (k = 1,..., K), indicate the

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[2] A related relevant concept defines that a function f is said to submodular if - f is supermodular.

innovation obstacles faced by the firm. The innovation function in that case would be given by:

$$I(C, \theta) = f(C_1, , , , , C_k, \theta) \qquad (2)$$

In that case where one has inverse proxies for innovation, the interpretation should be more careful. For barriers that have complementarities, specific target policies targeted policies should be considered, whereas the case of a substitution pattern between barriers would call for packages of innovation policies since the reduction of a given barrier exacerbates the effect of the remaining.

2.2- <u>Empirical Implementation and Econometric Issues</u>

The aforementioned innovation function can be empirically considered in terms of the expression below:

$$I_i = \sum_{l=0}^{2^k-1} \gamma S_{ij} + \beta Z_{ij} + \eta_j + \varepsilon_i \qquad (3)$$

where, I_i represents some outcome of the innovative activity by firm i, S_j refers to dummy variables indicating the prevalence of a given combination of policies, Z_t denote the remaining exogenous variables, η_j and ε_i are respectively sectoral fixed effects and the error term.

A first econometric issue that arise refers to the consistent estimation of equation (3). To address it, one needs to indicate the phase of the innovation process that is being considered. In the investigation of the propensity to innovate one observes data with both innovating and non-innovating firms and therefore standard models for limited dependent variable can be used (for example a probit model). The evaluation of the intensity of innovation, however, is more complex as

one would observe data on intensity only for innovating firms and therefore one is facing a truncated distribution. A traditional approach is to consider Heckman´s two step procedure where the inverse Mills ratio from an initial probit regression with the full sample is regressed as an additional correction term on the final ordinary least squares regression. The procedure known as heckit is often called generalized tobit.[3]

Another aspect that was neglected in the literature pertains the consideration of a weighted maximum likelihood estimation to account for complex sampling design. In fact, survey respondents are selected in accordance with distinct sampling weights and different modern statistical and econometric packages already incorporate the related procedures data [Kish (1965) and Silva et al. (2002) provide useful discussions on complex sampling]

A second econometric issue relates to the implementation of the tests for supermodularity of the innovation function that is considered for pairs of policies. Assuming a total of 4 policies, for policies 1 and 2 one has to face restrictions associated with 4 inequalities (where XX = {00,01,10,11}):

$$\gamma_{10XX} + \gamma_{01XX} \leq \gamma_{00XX} + \gamma_{11XX} \qquad (4)$$

whereas for pairs 1 and 3 one would have:

$$\gamma_{1X0X} + \gamma_{0X1X} \leq \gamma_{0X0X} + \gamma_{1X1X} \qquad (5)$$

and for polícies 2 and 3:

$$\gamma_{X10X} + \gamma_{X01X} \leq \gamma_{X00X} + \gamma_{X11X} \qquad (6)$$

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[3] See Greene (2003) for an introductory discussion.

In order to prevail complementarity among policies 1 ,2 and 3, it is necessary not to reject the validity of the null hypothesis relating to those restrictions in all tests. Similarly, the same follows in the case of inclusion of the fourth incentive policy.

The hypothesis test needs to consider multiple linear restructions. Letting, with slight abuse of notation, the k coefficients be represented by the vector $\mathbf{b}$ ($kx1$), the inequality test assesses the null hypothesis $H_0 = \mathbf{Rb} \leq 0$ against the alternative hypothesis $H_1 = \mathbf{Rb} \geq 0$, where $\mathbf{R}$ is a pxk matrix, p is the number of restrictions, and under the null hypothesis a strict inequaliity holds for at least one of the restrictions. The relevant test statistic is provided by Kodde e Palm (1986)):

$$c_w = (\mathbf{R}(\mathbf{b} - \overline{\mathbf{b}}))^{\mathbf{T}} (\mathbf{R\Omega R^T})^{-1} \mathbf{R}(\mathbf{b} - \overline{\mathbf{b}}) \qquad (7)$$

where $\mathbf{b}$ indicates a consistent estimator for the parameter vector and $\overline{\mathbf{b}}$ refers to the estimator that minimizes the previous expression subject to the null hypothesis. Gourieroux et al. (1981) and Wolak (1989, 1991) have shown that the appropriate a statistic for such test follows a weighted chi-square distribution. The probability of the test statistic exceeding c under the null hypothesis is given by $\sum_i \Pr(\chi_i^2 \leq c).w_i$, where w_i is the relevant weight [see e.g. Shapiro (1985) and Wolak (1989)].[4] The relevant critical values appear in table 1 from Kodde e Palm (1986). The lower and upper bounds (c_l and c_u) at significance levels ranging from 0.25 up to 0.001 and degrees of freedom fro 1 to 40 for tests involving multiple equalities and

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[4] Moreover, Shapiro (1985) shows that those weights add to 1.

inequalities. [5] If the test statistic lies between c_l and c_u the test would not be conclusive. It is important to stress that consistent estimation of the coefficients is required for implementing the test and potential endogeneities could pose an important challenge. Mohnen e Röller (2005), however, ponder that such caveat does not directly jeopardizes the analysis as even with inconsistent estimates, the error term would be correlated with the interaction terms and not with the practices themselves.

3. Empirical Analysis

3.1- <u>Data</u>

The study relies on a comprehensive survey on technological innovation in the context of the Brazilian industry [Pesquisa de Inovação Tecnológica-PINTEC, Instituto Brasileiro de Geografia e Estatística-IBGE].[6] The referred survey considers active firms with main revenues associated with extractive or manufacturing industry and with 10 or more employees. We were granted special access to the micro data of PINTEC-2003. It is important to stress that the questionnaire closely follows the one from the Community Innovation Survey (CIS 1) that was conducted for European countries and used by Mohnen and Röller (2005). Nevertheless, it is worth emphasizing that in the Brazilian case one does not face a micro-aggregation limitation. The survey was carried out in 2000, 2003

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[5] Following Kodde and Palm (1986), the degrees of freedom equal one plus the number of equalities tested for the lower bound and the total number of equalities and inequalities for the upper bound.
[6] The questionnaire and other details are presented in IBGE (2005)

and 2005. The quantitative data and a few qualitative ones (like for example unfinshed projects) refer to the current year of the survey. The majority of the qualitative data refer to the period of the current year and the 2 consecutive previous one (in the case of PINTEC-2003, from 2001 until 2003).

A stratified sampling procedure is adopted where the first stratum is defined in accordance with the probability of the firm being an innovator. The allocation of a firm to a stratum depends on a set of indicators (primary and secondary). The first subset, the certain stratum, comprises large firms (with 500 or more employees) or yet firms that had declared themselves as innovators in the previous edition of the survey that are included with probability 1.

Two additional classes of stratum are considered in terms of the eligible and non-eligible categories, In the former one includes firms with reasonable chances of being innovators whereas in the latter one includes firms with slim or none chance of being innovators.

In order to guarantee reliable information for the different regions, a second stratum level considered different cut-off points depending on the importance of the economic activity. In the case of the most important industrial state (São Paulo), for example the criterion was 80 % of the industrial transformation value. The selection of the sample in the final stratum considers selection probability that is proportional to the square root of the number of employees. Altogether, the previous observations indicate a complex stratified sampling that should be acknowledged in the estimation as the Brazilian case is characterized by non-negligible sectoral and geographical heterogeneities.

Prior to defining the sample, we excluded firms with R&D intensity above 50% that could be outliers, Moreover, sectoral dummies were considered in terms of 16 industrial sector was considered (in terms of the Classificação Nacional de Atividades Econômicas-CNAE-IBGE). The referred sectors are listed in the appendix. Next we describe the variables considered in the econometric estimation.

Table 1 – Definition of variables

Endogenous variables:	
Propensity to innovate	Dummy variable assumes value 1 if the firm has innovated in process or product, for the market or only for the firm, and. 0 otherwise.
Intensity of innovation	Revenues from innovating products divided by total revenues when the main market is national, and net exports of innovating products divided by total exports when the main market is abroad.
Exogenous variables:	
Log(EMP)	Logarithm of the number of employees.
Foreign	Dummy variable assumes value 1 if the firm has dominant share of foreign capital and 0 otherwise
Group	Dummy variable assumes value 1 if the firm is part of a group and 0 otherwise.
Organizational	Dummy variable assumes value 1 if the firm implemented a significant organizational change and 0 otherwise.
Exporting	Dummy variable assumes value 1 if the firm exports and 0 otherwise.
R&D intensity	R&D expenses divided by net sales revenues
Continuous	Dummy variable assumes value 1 if the firm makes continuous R&D expenditures and 0 otherwise.
Cooperation	Dummy variable assumes value 1 if the firm cooperates with other institutions and 0 otherwise.
Sectoral dummies	Dummy variables for the sectors listed in the appendix
Regional dummies	Dummy variables for the Brazilian macro regions (North, Midwest, Northeast, Southeast, South)
Obstacles to innovation (dummy variables constructed upon combinations)	
O1	Lack of appropriate finance sources
O2	Lack of skilled personnel
O3	Lack of opportunities for cooperation with other firms/institutions
O4	Lack of information on technology or on the market

The variables are similar to those considered in Mohnen and Röller (2005), As for policies variables we also focus on perceived obstacles to innovation, but consider the categories referring to risk and finance, knowledge-skill within

enterprise and Knowledge-skill outside the enterprise, In the first category we considered the obstacle referring to the lack of appropriate sources of finance. In the second category, we considered the lack of skilled personnel and lack of information on technology or on the market. In the third category, we focused on the lack of opportunities for cooperation with other firms/institutions. Next, tables 2 and 3 display some basic summary statistics and indicate substantial heterogeneity,

Table 2 - Summary statistics (expanded sample[7])

	Mean	Std. error	Confidence interval 95%	
Propensity to innovate	0.330	0.007	0.315	0.344
Intensity of innovation	0.088	0.004	0.080	0.096
Number of employees	49.08	0.690	47.71	50.44

Source: PINTEC-IBGE, 2003

Table 3 - Summary statistics (expanded sample)

	Did not innovate				Did innovate			
	Mean	Std. error	Confidence interval 95%		Mean	Std. error	Confidence interval 95%	
Foreign	0.014	0.002	0.011	0.017	0.030	0.002	0.025	0.034
Group	0.025	0.002	0.020	0.029	0.043	0.004	0.035	0.050
Organizational	0.584	0.010	0.565	0.603	0.834	0.010	0.813	0.854
R&D intensity	-	-	-	-	0.007	0.001	0.005	0.008
Continuous	-	-	-	-	0.071	0.005	0.062	0.080
Cooperation	-	-	-	-	0.029	0.003	0.022	0.036

Source: PINTEC-IBGE, 2003

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[7] Summary statistics of the sample are available upon request

Table 4, in particular, provides an idea of the relative importance of the perceived obstacles to innovation.

Table 4 - Relative frequency of obstacles to innovation (expanded sample)

No obstacle was encountered	69.00%
Finance source	28.16%
Skilled personnel	12.80%
Opportunities for cooperation with other firms/institutions	7.88%
Information on technology or market	12.30%
High economic risks	24.74%
Scarcity of adequate technological services	6.67%

Source: PINTEC-IBGE, 2003

4. Empirical Analysis

In this section we present the empirical results from the econometric estimation that were carried out with Stata SE 10.0.An important feature of that software is that it allows to incorporate sampling weights in the maximum likelihood estimation. The related results appear in tables 5 and 6. For conciseness reasons, we do not report the results regarding the sectoral and regional dummies, but important differences emerge when comparing estimates that incorporate complex sampling or not. We will use the results that incorporate sampling weights as presented in table 5 as our preferential results. The results depends on the phase of the innovation process, In the equation referring to the propensity of innovation the regional dummies exert no significant effect when one considers individual coefficients, In the case of sectoral dummies only coefficient is clearly significant and two others are marginally significant. As for the variables indicating combination of obstacles we will not emphasize the discussion of individual coefficients but rather discuss complementarity tests later in this section. Some

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other plausible results emerge in terms of positive and significant coefficients for the firm size variable (LEMP), the organizational change variable and for the exporting variables that is denotative of competitive pressures.

When one considers the intensity of innovation, the previous results essentially prevail but additionally one observes a clearly significant positive coefficient for organizational change, Moreover, if a significance level slightly above 5 % is considered, it is possible to detect important positive effects accruing from ownership, participation in groups and R&D intensity.

Next, we consider the main issue of the paper namely that of testing for the presence of complementarities in innovation policies (or obstacles to innovation).[8] The interpretation of the test statistics reported in table 7 run as follows. Values above the upper bound critical value at a 10% as given by 7.094 indicate a rejection of the null hypothesis. Values below lower bound critical value of 1.642 would favour acceptance of hypothesis, whereas intermediate values between the referred bounds would indicate that the test is inconclusive. When the test focuses on supermodularity, acceptance of the null hypothesis would indicate the prevalence of complementarity in obstacles to innovation. When submodularity is considered instead, the acceptance of the null hypothesis would signal the presence of substitutability in obstacles to innovation.

In the study of Mohnen and Röller (2005) the results were clear cut in the sense that in general substitutability in obstacles to innovation prevailed when considering the propensity to innovate and complementarity was salient when one

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[8] We thank Pierre Mohnen for kindly providing the Gauss code for implementing the inequality restrictions tests.

considers the intensity of innovation. In the present investigation the results are less clear.

Starting with the assessment of the propensity to innovate the results are not strong and do not spread along several different pairs of obstacles. There is evidence of complementary of obstacles between the lack of information on technology or markets (OBS4) and lack of skilled personnel (OBS2) and yet lack of cooperation opportunities (OBS3). For example, for the pair of obstacles 2-4 the test statistic would be 0.321 and favour supermodularity (complementarity). The test for submodularity, on the other hand, only favours the acceptance of the null hypothesis of substitutability between lack of finance sources and lack of information (pair 1-4).

When we consider the intensity of innovation, the results are stronger. In the case of the test for supermodularity we cannot reject the null hypothesis for any of the pairs (the largest value for the test statistics was 1.593 for pair 2-3). As for the test of submodularity evidence indicates substitutability between lack of cooperation opportunities with both lack of finance sources and lack of skilled personnel (respectively pairs 1-3 and 2-3). Please note that pair 2-3 shows ambivalent evidence and given the generous confidence level adopted one should refrain from a strong conclusion in that case. Finally, submodularity appears to prevail between lack of cooperation opportunities and lack of information (pair 3-4).

Altogether, the evidence contrasts somewhat with previous evidence for European counties. In particular, there is only limited evidence for substitutability or complementarity for few pairs of obstacles. When one considers the intensity of

innovation the evidence strongly indicates the presence of complementary

obstacles,

Table 5 – Regression results (models using sampling weights)

Variables	Propensity to innovate			Intensity of innovation		
	coef.	std. error	p-value	coef.	std. error	p-value
Log(EMP)	0.091	0.021	0.000	-0.044	0.009	0.000
Foreign	0.087	0.089	0.332	0.055	0.029	0.061
Group	0.097	0.093	0.297	0.072	0.040	0.074
Organizational	0.649	0.052	0.000	-0.145	0.033	0.000
Exporting.	0.205	0.054	0.000	-0.044	0.023	0.055
R&D intensity	-	-	-	0.504	0.267	0.059
Continuous	-	-	-	0.023	0.024	0.342
Cooperation	-	-	-	0.035	0.038	0.348
States:						
0001	-0.742	0.444	0.095	0.288	0.167	0.087
0010	-0.150	0.692	0.828	0.676	0.274	0.014
0011	1.650	0.715	0.021	0.291	0.169	0.085
0100	-0.021	0.472	0.964	0.398	0.162	0.014
0101	0.318	0.474	0.503	0.362	0.155	0.020
0110	-0.759	0.725	0.295	0.286	0.220	0.193
0111	0.342	0.677	0.613	0.442	0.211	0.036
1000	-0.808	0.341	0.018	0.473	0.154	0.002
1001	-0.699	0.356	0.050	0.426	0.156	0.006
1010	-0.739	0.380	0.052	0.531	0.168	0.002
1011	-0.488	0.372	0.189	0.429	0.167	0.010
1100	-0.916	0.353	0.009	0.503	0.160	0.002
1101	-0.323	0.350	0.356	0.453	0.155	0.004
1110	-0.459	0.384	0.231	0.511	0.172	0.003
1111	-0.198	0.353	0.574	0.404	0.155	0.009
0000	-1.073	0.336	0.001	0.489	0.152	0.001
Lambda				0,0249	0,0143	0.041

Table 6 – Regression results (models not using sampling weights)

Variables	Propensity to innovate			Intensity of innovation		
	coef.	std. error	p-value	coef.	std. error	p-value
Log(EMP)	0.138	0.013	0.000	0.007	0.015	0.650
Foreign	0.122	0.059	0.037	0.085	0.029	0.003
Group	-0.010	0.051	0.851	0.036	0.025	0.148
Organizational	0.679	0.035	0.000	0.176	0.080	0.027
Exporting.	0.249	0.035	0.000	0.051	0.030	0.088
R&D intensity				0.386	0.202	0.056
Continuous				0.047	0.017	0.005
Cooperation				0.042	0.024	0.070
States:						
0001	-1.600	0.290	0.000	-0.680	0.335	0.043
0010	-1.156	0.481	0.016	-0.226	0.341	0.508
0011	-0.481	0.585	0;411	-0.342	0.307	0.266
0100	-0.632	0.306	0.039	-0.372	0.264	0.159
0101	-0.621	0.326	0.057	-0.471	0;265	0.076
0110	-1.349	0.498	0.007	-0.231	0.370	0.533
0111	-0.810	0.437	0.064	-0.269	0.301	0.371
1000	-1.503	0.218	0.000	-0.626	0.314	0.047
1001	-1.364	0.229	0.000	-0.564	0.304	0.064
1010	-1.418	0.241	0.000	-0.532	0.312	0.088
1011	-1.232	0.245	0.000	-0.529	0.297	0.077
1100	-1,435	0.228	0.000	-0,542	0.310	0.080
1101	-1.086	0.225	0.000	-0.472	0.280	0.092
1110	-1.239	0.252	0.000	-0.530	0.299	0.076
1111	-0.964	0.228	0.000	-0.452	0.272	0.097
0000	-1.868	0.215	0.000	-0.722	0.349	0.038
Lambda				0.531	0.1576988	0.001

Table 7 – Wald tests for inequality restrictions (at the 10 % significance level, the lower bound is given by 1.642 and the upper bound is given by 7.094) – Obstacles to innovation

Pair of obstacles	Propensity to innovate						Intensity of innovation					
	1-2	1-3	1-4	2-3	2-4	3-4	1-2	1-3	1-4	2-3	2-4	3-4
Supermodularity test:												
	12.826	10.766	4.238	9.148	0.321	1.555	1.145	0.918	1.26	1.593	0.002	1.038
Submodularity test:												
	4.178	2.545	0.266	1.79	5.755	3.366	3.367	0.337	3.847	0.151	5.2	0.694

Definition of obstacles: 1 – Lack of appropriate finance sources; 2 - Lack of skilled personnel; 3 - Lack of opportunities for cooperation with other firms/institutions; 4 - Lack of information on technology or on the market

5. Final Comments

The paper aimed at investigating the presence of complementarities in innovation policies in the Brazilian industry in term of inverse proxies for innovation (obstacles). The paper benefits from micro-data that are not subject to limitations related to micro-aggregation and explicitly considered sampling weights in the estimations. The analysis considered tests fot supermodularity and submodularity of an innovation function taking as references obstacles to innovation referring to lack of adequate finance sources, lack of skilled personnel, lack of opportunities for cooperation with other firms/institutions and lack of information on technology or on the market. The study highlighted the different phases of the innovation process in terms of the propensity of innovation (in terms of a Probit model) and the intensity of innovation (in terms of a generalized Tobit model).

The results did not indicate clear distinct patterns in the two phases of the innovation process like in Mohnen and Röller (2005). In fact, we find limited evidence favouring substitutability and complementarity in obstacles in the case of the propensity to innovate. Specifically, there is some evidence that suggests the relevance of a package of policies relating to finance sources and information on technology or the market. On the other hand, if we consider the intensity of innovation the evidence is stronger and indicates complementarities of obstacles and the need for more targeted policies.

Even though the results are suggestive, stronger policy recommendations would be clearer if further research combines different years of that survey in the future. Additionally, the reliance on an indirect approach based on obstacles to innovations has shortcomings. Indeed, the perception that innovation has been

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curbed by some particular obstacle can be subjective as one is not sure that an innovation would actually occur if that barrier did not prevail. A relevant extension should consider direct measures reflecting actual incentive policies for innovation, what of course would require better data.

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Appendix

Definitions of the industrial sectors

Sector	CNAE codes	Number of firms	%
Extractive	10, 11, 13, 14	1863	2,25%
Food, drinks and tobacco	15 e 16	10400	12,56%
Textile	17	3089	3,73%
Clothing	18	11592	14,00%
Leather	19	3792	4,58%
Wood products	20	5010	6,05%
Cellulose, paper and printing	21 e 22	5274	6,37%
Coke, fuel	23	166	0,20%
Chemicals	24	3329	4,02%
Pharmaceuticals	25	4968	6,00%
Non-metallic minerals	26	6632	8,01%
Metallurgy and metal products	27 e 28	8727	10,54%
Machinery and equipments	29	5332	6,44%
Electric and electronic machinery and equipment	30, 31, 32, 33	3296	3,98%
Transportation vehicles and others	34 e 35	2360	2,85%
Others	36 e 37	6972	8,42%
Total		**82.802**	**100,00%**

Source: own elaboration upon data from PINTEC-IBGE, 2003

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