A Regression Discontinuity Approach to Assess the Effectiveness of Tax Incentives Programs to Support Business R&D: the Mexican Experience

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Introduction

In 2008 the Mexican government implemented a fiscal incentive program to support businesses that invest in research and technological development (R&D). It consisted in granting a tax credit to beneficiaries, amounting to 30% of R&D expenditure. to be deducted from corporate tax liability.[2]

With the allocation of public funding for this fiscal incentive plan, the Mexican economic authorities recognized that, due to market failures and coordination problems among agents and institutions within the national innovation system, private companies do not carry out certain research and technological development projects because they are not commercially viable, even though their economic cost is lower than the overall benefit generated to the country.

Two peculiarities in the implementation of the Mexican program make the assessment of its effectiveness to achieve desired results possible by means of a Regression Discontinuity Design identification strategy.

On one hand, obtaining the tax credit to implement an R&D project was not automatically granted. All firms wanting a fiscal credit had to apply to participate in the program and to present their R&D and innovation projects to the agency in charge of implementing the program. Experts appointed by this agency assessed the feasibility of the project proposals and gave them a numerical grade between 1 and 100. This grade was then used for two purposes: to discard as candidates for a tax credit those firms whose projects

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[2]In 2007, 21 OECD had incentives schemes of this kind. A number of developing countries such as Brazil, China, India and South Africa also had them. Unlike other countries that kept using fiscal incentives to foster private innovation, Mexico suspended its program in 2009 and it is not until 2017 that it reestablished it.

did not obtain a minimum approval grade and to rank in descending order those considered to be feasible projects.

On the other hand, the administrators of the program relied on the rank ordering established by the grades of approved projects to allocate a limited amount of total tax credit that could be distributed among companies during that year. A ceiling in the budget of the program was established by the ministry of Finance and was binding, since the amount of fiscal credits asked for by companies with projects grades above the minimum to be considered feasible surpassed the amount allocated to the program.

The allocation criteria followed by the agency in charge of the program implementation was to benefit those companies whose projects were ranked better in terms of the numerical grades given to them by their appointed experts. A numerical threshold was implicitly established and was given by the lowest grade obtained by the project of the last firm that could be benefited from the program. Those firms whose projects were graded with a number below that threshold (but above the minimum approval grade to be considered as a feasible project) would have obtained their tax credit, if the total amount of resources allocated to the program by the ministry of Finance had been more generous.

In this paper we assess what would have happened to the subsidized companies' patents and patents applications during a period of 4 years, if they had not received the tax credit.

The control group is integrated by companies that got no tax credit at all, in spite of the fact that they presented proposals that obtained a grade above that established to be considered feasible. The treatment group is integrated by companies which were granted at least one of the fiscal credits they were applying for.

The grade given to all projects, whether in the treatment or control group, was available as an input in this paper. In addition to a number of pre-treatment variables, we obtained outcome results from International and National official patent offices information regarding patents and patent applications f registered between 2009 and 2012.[3]

Our analysis shares with the work of Bronzini and Iachini (2014) and Bronzini and Piselli, 2014, the use of rating given to funding applications, as a way of generating exogenous variation around a funding threshold.[4] However, unlike their work that use a sharp regression discontinuity design to compare the investment spending of subsidized firms with that of unsubsidized firms, ours

[3]These were obtained by a center specialized in obtaining this kind of data from electronically accessible banks that verified which firms in the list of names of companies that were used in these study succeed in their innovation efforts.

[4]Another evaluation of a similar program, which also uses a RD design is the one undertaken by Dechezlepretre *et. al*, 2016. These authors use the value of assets as their running variable, exploiting a policy reform in the UK which raised the size threshold under which firms can access the more generous tax regime for small-and medium sized enterprises.

use a fuzzy regression discontinuity design. This is because the Mexican program allowed companies to apply for more than one project to be supported by the program and some firms had some approved but others rejected.

In their evaluation, Bronzini and Piselli, 2014, found that program funding of R&D projects implemented in Northern Italy enhanced the number of patent applications submitted by recipient firms. Their results also suggest that the program was also successful to increase small enterprises probability of patenting. In contrast to their findings, our evaluation found that the Mexican program was ineffective in achieving these results.

The study includes five sections in addition to this introduction. Section 2 describes the program, the institutional setting and reviews recent studies for other countries that share the methodology applied for the Mexican case. Section 3 describes the database and Section 4 presents the empirical strategy, including the tests of the validity for the RD design to be valid.
specifies the functions to estimate. Section 6 discusses the results in terms of the amount program beneficiary companies would have invested in research and technological development if they had not received the fiscal stimulus in 2005 and 2007. Our empirical analysis of the relationship between investments in research and technological development and the introduction of innovative products into the market has been relegated to Section 7. The last section presents the conclusion and recommendations.

2. The Program

2.1 *Analytical justification* of *tax incentives programs to support business R&D activities*

According to theory, private investment in generating new knowledge and in technological development would, as a whole, be economically and socially adequate for a country if businesses were not affected by market failures and by coordination issues between national innovation system agents and institutions. The amount invested would cover all R&D projects whose economic and social benefits compensate for execution costs.

Since these market and coordination failures affect technological development and innovation activities of businesses, they are not able to reap the benefits attributable to investing in them. Also, as a result of these market failures, it is very difficult to prevent companies and individuals other than those who invested in their development from benefitting without having to pay for it and a number of problems to finance these projects arise and funding costs increase.[5]

To mitigate the negative effect of these failures and encourage businesses to carry out projects that would have been discarded without public intervention,

[5] In addition, agents are reluctant to take financial risks associated with research and technological development projects because, unlike other types of investments, there is not enough information available to determine their probability of success.

the government can grant fiscal stimulus for company R&D projects to make them profitable from a private perspective.

The effectiveness of this program in achieving the purpose for which it was designed is achieved when it encourages businesses to spend an amount of resources above that which they would have done if they had not been beneficiaries of the program and when their projects result in patents and/or innovative products and services.

The purpose of the tax credit scheme was to provide a built-in incentive for companies to increase their research activities by allowing them to deduct 30% of their corresponding expenditures in R&D from their corporate taxes, and thus lowering their cost and increasing their expected returns.

2.2 *Institutional Setting and characteristics of the Mexican Program*

All firms that apply to participate in the program had to present their R&D and innovation projects to the agency in charge of its implementation; only those that were graded as technically approved by CONACYT were candidates to benefit from the tax credit. The rejection of approved applications was due to the resource constraint that restricted the total amount of fiscal incentive credits to be granted during this year. CONACYT kept records for both beneficiaries of the program and applicants with technically approved projects, whose companies were not granting the incentive they were applying, in spite of the fact that they were technically approved.

2.3 *Evaluation studies of Tax credit programs in other countries*

The most relevant econometric evaluation results of the effectiveness of Tax incentive programs to promote R&D in private business have been reviewed in a number of papers, among them Bronwyn Hall y John Van Reenen (2000) and Ientile and Mairese (2009). As it has been referred there, most studies rely on the so-called difference-in-difference analysis or matching techniques or self-selection methods to address the identification problem intrinsic in the econometric evaluation of the program. It is has been well established that, if implementing a randomized experiment that would imply that only some randomly selected firms receive the tax credit and others not, is not possible, a RDD approach is preferable to other evaluation methods (Hahn, 2001). The quasi-randomness of the assignment of the treatment around the cut-off, makes beneficiary and non-beneficiary companies around the threshold comparable.

3. Data Description

The information used here required merging micro-datasets from the following two sources: a) the administrative records of the agency in charge of the R&D and innovation fiscal incentive program (CONACYT) and b) electronic available official banks of registered patents, patent applications and applications of other author ownership rights.

Our sample is constituted by 1903 R&D projects presented in 2008 to the agency in charge of the fiscal incentive program (CONACYT). All of them were given to three referees for their technical assessment and received the minimum average mark required for a project to be considered a feasible. They were presented by 443 companies –more than one project could be subsidized to a single company.

Given that the amount of fiscal credits asked for by companies with projects grades above the minimum to be considered feasible surpassed the global allocation of fiscal credits to the program, only 1087 of these projects received the support they were applying for. This implied that only 333 out of the 443 companies that could have benefited from the program got at least one project financed.[6]

From CONACYT administrative records we obtained the list of names of companies that participated in the program, information associated with the criteria to select beneficiaries, average grade obtained by each project and a number of pre-treatment characteristics of the companies.

The sample of projects and companies incorporated in this analysis is not representative sample of all program participants; it is constituted by the participants of the tax credit program that were included in the 2012 Innovation survey.[7] This latter survey is representative sample of the universe of firms engaged in innovation activities in Mexico and included the majority of participants of the program we are assessing in this paper.[8]

As shown in Table 1, the grade that was the threshold to divide between supported and rejected applications was 54 points. Projects that got a grade equal or above it were granted a tax credit amounting to 30% of R&D expenditure to be deducted from corporate tax liability; those with a grade below it had their application rejected.

Table 1
R&D projects

[6] On average, each company received 2.8 million pesos.

[7]A more complete version of this paper includes the impact of the program on new products or services introduced to the market between 2008 and 2011, which is an information provided by this survey. In addition, personal of INEGI has extracted information from the Economic Census of 2008 micro data set of the companies that integrate our control and treatment groups. In this version of the paper the set of pre-treatment variables will be enlarged in order to provide more consistency to the test that all covariates were balanced at the cut-off.

[8]Even though the sample we work with is not necessarily representative of the universe of beneficiary companies, results presented in the following sections should be relevant in terms of measuring program effectiveness, given the group of companies it was possible to work with. This is a valid procedure, given that the purpose of these evaluations is not to make an efficiency or a cost-benefit analysis but to analyze program effectiveness. Thus, precise estimates rather than adequate program participant representation are required.

threshold grade 54 points		Total
Projects	Not approved (Below threshold grade)	846
	Approved (above threshold grade)	1,087
Total		**1,903**

In figure 1, the normalized values of grades obtained by these projects is graphed.

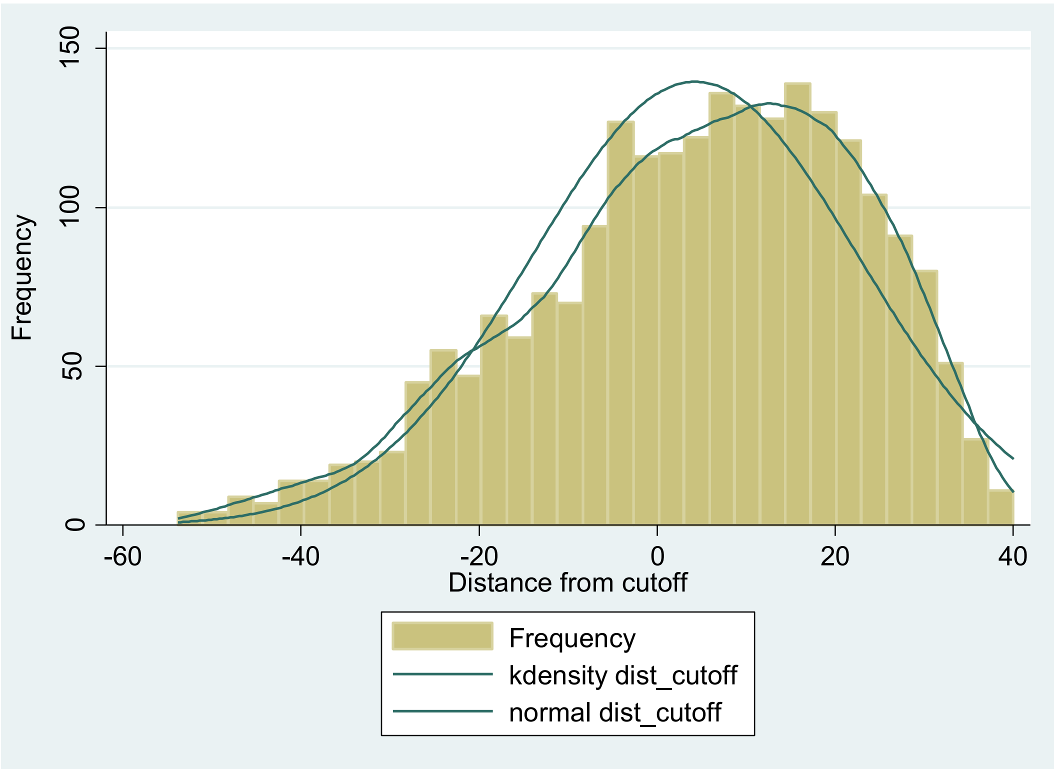


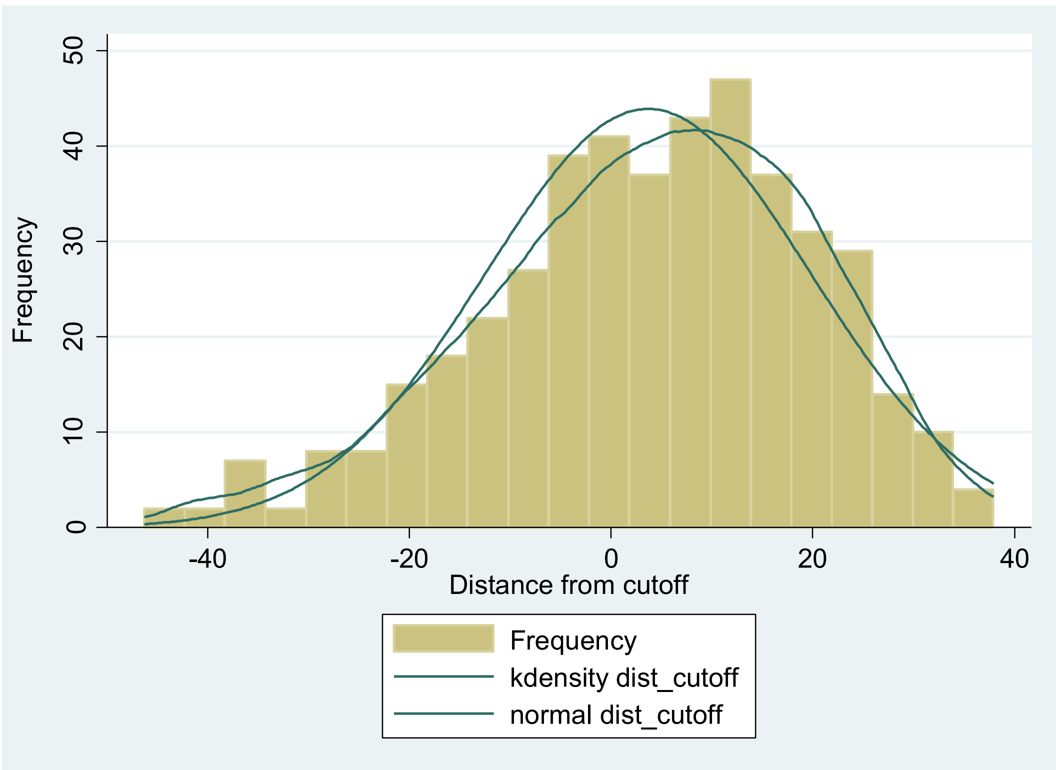
Figure 1. Histogram with normalized values of grades obtained.

A firm could obtain a tax credit for more than one project. Since our unit of analysis is the firm and not the individual project, we obtained a weighted average mark by company, using as weights the share of that the project represented in total amount of fiscal support the firm applied for. The control group is integrated by companies that got no tax credit at all, in spite of the fact that they presented proposals that obtained a grade above that established to be considered feasible. The treatment group is integrated by companies which were granted at least one of the fiscal credit they were applying for.

As shown in table 2, 61 out of 333 business had a weighted average grade below 54, in spite of the fact that they benefited from the fiscal incentive program.

Table 2				
Companies				
		Above cutoff (54 points)		
		No = 0	yes= 1	Total
Treated (at least one project was approved)	No	110	0	110
	yes	61	272	333
Total		171	272	**443**

In figure 2 we graph the normalized values obtained by the weighted average grade obtained by each companies for the total projects that it presented.



4 Empirical Strategy

4.1 *Outcome equation*

Some of the companies that benefited from the program (14% of them) had a weighted average grade that, as shown in Table 2, resulted below the threshold. Because of this, fuzzy RDD techniques needs to be applied.[9]

The outcome of the program is patenting or applying for patenting registration within a period of 4 years after program participation.

The running variable is the weighted average grade obtained by a company for the projects it presented and the threshold is a grade equal to 54 points out of 100.

We have the following two regressions to be estimated:

First stage:

$$\{1(Treated_i > 0)\} = \rho + \mu\{1(NormGrade_i > 0)\} + \tau_i \quad (1)$$

Second stage:

$$Y_i = cons + \beta\,\{1(\widehat{Treated_i} > 0)\} + \alpha\{\,(NormGrade_i)\times 1(NormGrade_i < 0)\} + \eta\{(NormGrade_i)\times 1(NormGrade_i > 0)\} + e_i \quad (2)$$

4.2 *Choice of Band Width*

We first applied the methodology in Imbens & Kalyanaram, 2012, to choose the optimal band width to apply the RDD tests.

The optimum band width is 4.86 points. This implied including all observations found in the interval [-4.86, 4.86] and keeping 20.54% of the sample (91 observations).

We also included 2 arbitr*ary* band widths more. Based on these widths, which we call medium and large, we keep 33& and 66% observations of the sample:
Band width medium is of size 9. This implied including all observations found in the interval [-9, 9] and keeping 37.24% of the sample (165 observations).
Band width large is of size 20. This implied including all observations found in the interval [-20, 20] and keeping 74.9% of the sample (332 observations).

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[9] We also implement a RDD for the case of individual projects, there we apply sharp regression techniques.

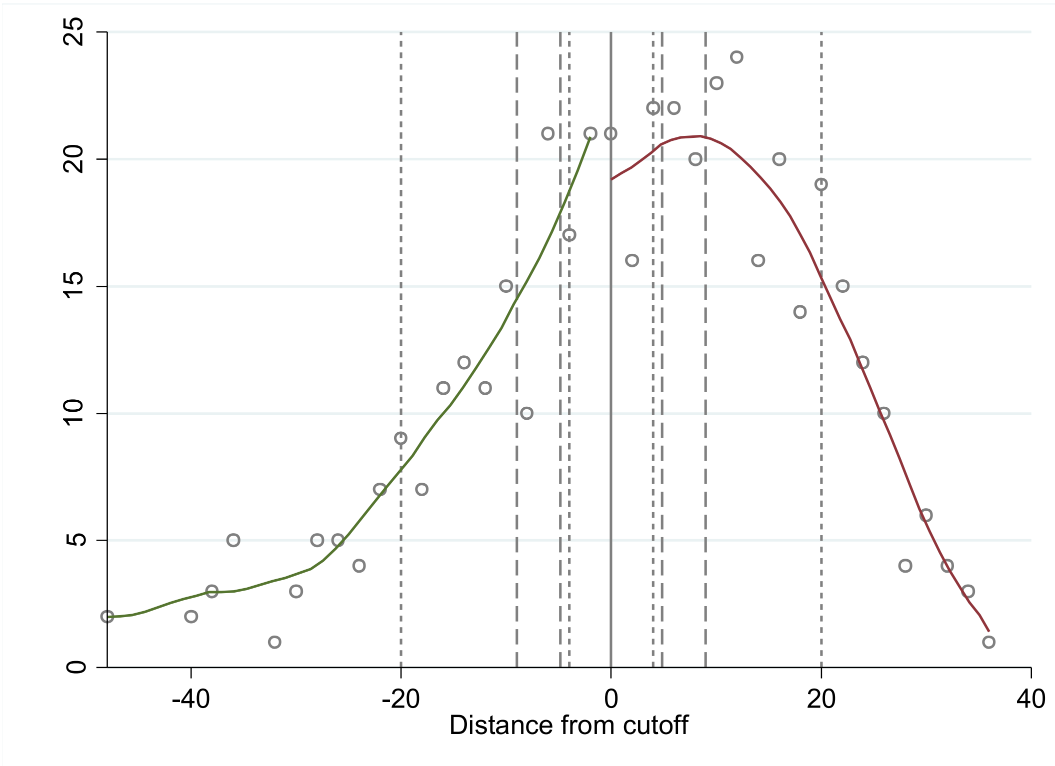
4.3 Tests of the validity of the RD design

4.3.1 *Discarding the bunching of the running variable around the threshold*

We show next the statistical absence of non-random distributions in the running variable, in order to discard that companies just below the threshold were able to actively influence their grades to be above the threshold. A situation where companies just below the cutoff differ systematically is unlikely to arise because participants have no direct control over the score their application receives and the threshold is only known once the global funds allocated to the program are exhausted.

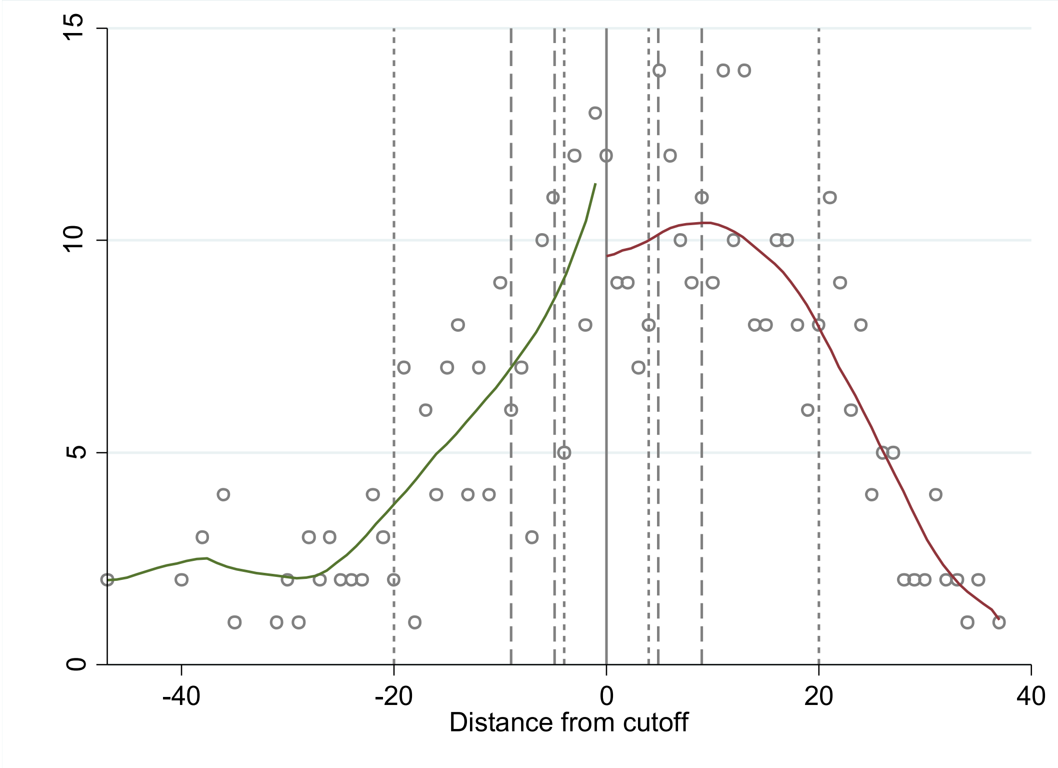
We conduct next, formal test to discard this possiblity. Each point in the following figures corresponds to the distribution of the number of companies whose weighted grade falls in the corresponding cell size interval. The figures also show the predicted cell sizes based on a local linear regresión.[10]

Interval size: 2

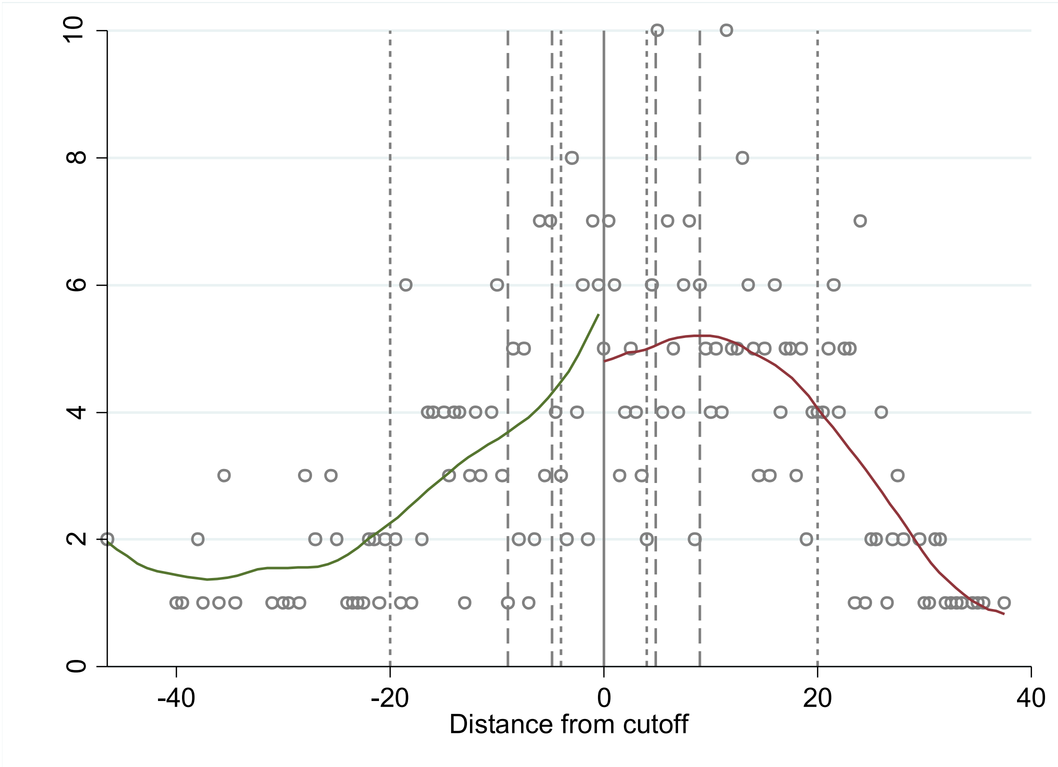


[10] This was done with the STATA comand lpoly, kernel(epan2) degree(1) bwidth(9))

Interval size: 1:



Interval size: 0.5:



For each size band, a regression was run to find out if there is a statistically significant discontinuity at the threshold grade, considering the different interval sizes. Results are shown in Table 3.

In all cases, estimated discontinuity at the threshold is not statistically significant, indicating that the distribution is continuous at the threshold, for different values of cell sizes and bandwidths

	Optimal band width		
	(1)	(2)	(3)
VARIABLES	0.05	1.00	2.00
above_cutoff	0.014	-3.500*	-11.667*
	(1.525)	(1.448)	(1.610)
dist_rcutoff	-0.533	-0.500	3.000***
	(0.523)	(0.251)	(0.000)
dist_lcutoff	0.473	1.500	1.000
	(0.304)	(0.788)	(0.527)
Constant	5.764***	13.000***	21.667**
	(0.875)	(1.368)	(1.610)
Observations	19	9	5
R-squared	0.151	0.550	0.909

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	Medium band width			Large band width		
	(1)	(2)	(3)	(1)	(2)	(3)
VARIABLES	05	10	20	05	10	20
above_cutoff	-0.837	-3.611**	-5.400	0.453	-0.196	0.312
	(1.208)	(1.554)	(3.959)	(0.872)	(1.547)	(2.824)
dist_rcutoff	0.052	0.300*	0.600	-0.047	-0.072	-0.152
	(0.169)	(0.143)	(0.605)	(0.045)	(0.083)	(0.195)
dist_lcutoff	0.319**	0.733***	1.100	0.128**	0.370***	0.686***
	(0.153)	(0.201)	(0.627)	(0.051)	(0.090)	(0.084)
Constant	5.647***	12.000***	22.400***	4.951***	10.654***	20.955***
	(0.808)	(1.188)	(1.568)	(0.619)	(1.122)	(1.338)
Observations	37	19	9	77	41	21
R-squared	0.129	0.382	0.516	0.168	0.461	0.708

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3.2 *Discarding that* pre-treatment variables are unbalanced

As a second step to test the validity of the RD design followed in this paper, we show that a number of pre-treatment variables are balanced. By means of regressions, for different band sizes, we reject there is a statistically significant discontinuity at the threshold point.

These variable are: five different sizes, (dsize1, dsize2, dsize3, dsize4, dsize5) defined according to categories based on number of employees and all of them captured with dummy variables that have a value of 1 if they fulfill the criteria and zero otherwise; tot_amount, amount of fiscal credit granted to the company; proy_total, number of projects presented by the firm; proy_aprob, number of projects granted the tax credit to the firm.

	Optimal band width							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	dsize1	dsize2	dsize3	dsize4	dsize5	tot_amount	proy_total	proy_a
grade>cutoff	0.068	0.000	-0.126	-0.062	0.120	2.331	2.335	0.99
	(0.061)	(0.000)	(0.117)	(0.187)	(0.197)	(17.101)	(2.069)	(0.89
dist_rcutoff	0.001	0.000	0.011	-0.026	0.014	-1.892	-0.519	-0.0
	(0.021)	(0.000)	(0.031)	(0.042)	(0.051)	(2.206)	(0.460)	(0.21
dist_lcutoff	-0.000**	0.000	0.010	0.006	-0.016	-5.666	-0.206	0.02
	(0.000)	(0.000)	(0.032)	(0.053)	(0.052)	(5.825)	(0.391)	(0.19
Constant (mean control)	-0.000***	0.000	0.149	0.327**	0.524***	19.312	3.797***	1.741
	(0.000)	(0.000)	(0.095)	(0.145)	(0.143)	(15.164)	(1.037)	(0.56
Observations	91	91	91	91	91	91	91	91
R-squared	0.038		0.022	0.017	0.015	0.006	0.006	0.01

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	Medium band width							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
VARIABLES	dsize1	dsize2	dsize3	dsize4	dsize5	montoeleg_tot	proy_total	p
grade>cutoff	0.073	0.003	-0.115	-0.141	0.179	-13.788	1.189	
	(0.052)	(0.004)	(0.082)	(0.131)	(0.142)	(29.333)	(2.191)	
dist_rcutoff	-0.006	0.000***	-0.003	-0.010	0.020	-0.771	0.073	
	(0.009)	(0.000)	(0.007)	(0.016)	(0.018)	(1.199)	(0.316)	
dist_lcutoff	0.000***	-0.004	0.020*	0.040**	-0.057***	2.609	-0.105	
	(0.000)	(0.004)	(0.011)	(0.018)	(0.018)	(3.178)	(0.219)	
Constant (mean control)	0.000***	-0.003	0.174**	0.386***	0.443***	34.501	3.771**	
	(0.000)	(0.004)	(0.071)	(0.098)	(0.102)	(28.764)	(1.571)	
Observations	165	165	165	165	165	165	165	
R-squared	0.027	0.015	0.029	0.030	0.050	0.003	0.007	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	Large band width							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
VARIABLES	dsize1	dsize2	dsize3	dsize4	dsize5	montoeleg_tot	proy_total	pro
grade>cutoff	0.060**	-0.026	-0.072	-0.132	0.171*	-3.367	1.684	1
	(0.030)	(0.019)	(0.059)	(0.092)	(0.102)	(23.099)	(1.537)	(
dist_rcutoff	-0.004*	0.003	0.001	0.015***	-0.016**	-0.655*	-0.106	
	(0.002)	(0.002)	(0.003)	(0.006)	(0.006)	(0.353)	(0.070)	(
dist_lcutoff	0.000***	-0.000	0.004	0.007	-0.010	-0.291	-0.120	
	(0.000)	(0.001)	(0.005)	(0.007)	(0.007)	(1.723)	(0.109)	(
Constant (mean control)	0.000***	0.012	0.119**	0.271***	0.598***	25.061	3.961***	1
	(0.000)	(0.012)	(0.050)	(0.068)	(0.075)	(22.512)	(1.246)	(

Observations	332	332	332	332	332	332	332
R-squared	0.034	0.011	0.006	0.032	0.029	0.007	0.010

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4. Results

With the estimates in sections 4.3.1 and 4.3.2 we found support for the validity of our regression discontinuity design. We turn no to estimate the outcome equation.

Regression results of equation (2), once (1) has been estimated, are presented in Table 6.

The outcome of the program is measured with three different variables a) *dum_pat,* patenting by the company during 2008-2012, b) applications for patenting during this same period of years and c) *dum_anypat* which state for the sum of these two variables plus two other type of author registration rights, namely the so-called utility models and industrial designs, These three outcomes are denoted respectively, dum_solpat, and, The results are shown in the following tables.

Tax Incentives Program to Support Business R&D

Impact on patenting behaviour
RDD design
Instrumental variable estimation

	Optimal band width				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	dum_anypat	dum_pat	dum_solpat	dum_moduti	dum_disind
above_cutoff	0.532	-0.100	0.459	0.095	0.135
	(0.435)	(0.177)	(0.355)	(0.100)	(0.328)
dist_rcutoff	-0.089***	-0.007	-0.061**	-0.007	-0.046*
	(0.034)	(0.008)	(0.031)	(0.008)	(0.024)
dist_lcutoff	-0.015	0.021	-0.025	-0.005	0.007
	(0.058)	(0.025)	(0.044)	(0.008)	(0.044)
Constant	-0.175	0.139	-0.209	-0.056	0.059
	(0.366)	(0.160)	(0.285)	(0.064)	(0.272)
Observations	91	91	91	91	91
R-squared		0.043			

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	Medium band width

	(1)	(2)	(3)	(4)	(5)
VARIABLES	dum_anypat	dum_pat	dum_solpat	dum_moduti	dum_disind
above_cutoff	0.205	-0.027	0.237	0.033	-0.092
	(0.231)	(0.117)	(0.187)	(0.070)	(0.185)
dist_rcutoff	-0.020	-0.005	-0.028**	0.001	-0.002
	(0.017)	(0.005)	(0.012)	(0.008)	(0.014)
dist_lcutoff	-0.003	0.002	-0.001	-0.000	0.017
	(0.018)	(0.012)	(0.014)	(0.001)	(0.012)
Constant	0.005	0.060	-0.056	-0.016	0.189
	(0.175)	(0.103)	(0.138)	(0.034)	(0.139)
Observations	165	165	165	165	165
R-squared		0.014		0.000	0.023

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	Large band width				
	(1)	(2)	(3)	(4)	(5)
VARIABLES	dum_anypat	dum_pat	dum_solpat	dum_moduti	dum_disind
above_cutoff	0.071	-0.050	0.021	0.014	0.031
	(0.123)	(0.061)	(0.096)	(0.039)	(0.108)
dist_rcutoff	0.001	-0.001	0.002	0.002	-0.002
	(0.005)	(0.001)	(0.004)	(0.002)	(0.003)
dist_lcutoff	-0.001	0.003	0.000	-0.000	0.000
	(0.005)	(0.002)	(0.003)	(0.000)	(0.005)
Constant	0.070	0.071	0.048	-0.006	0.073
	(0.092)	(0.053)	(0.067)	(0.017)	(0.086)
Observations	332	332	332	332	332
R-squared	0.001	0.002	0.008	0.013	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

None of the relevant coefficients in the regressions presented in these last 3 tables is statistically significant. These results indicate then that we can reject the hypothesis of a positive impact on patenting behavior on beneficiaries that could be attributed to the Mexican tax credit program to support R&D of private companies during 2008.

To the extent that there are heterogeneous treatment effects, our estimates will not necessary capture the average treatment effect. Our instrumental variables instrument estimation captures the local average treatment effect (LATE). It implicitly compares the propensity of companies that received a tax credit to come up with patents or applications to register them, with the corresponding propensity of companies that would have had a tax credit if the total amount of resources allocated to the program by the ministry of Finance had been more generous.

VI. Conclusion

A founded discussion of the net benefits of this kind of programs is required in view of the continuous reference, in Mexico and other countries, that tax credit are more effective in supporting companies R&D performance than other programs –such as those providing grants to support yearly activities of the firm.

The same tax credit program to support R&D of private companies has been re-established in 2017, after 8 years of not being offered. The lack of evidence found in this paper regarding the effectiveness in improving patenting behavior of beneficiary firms during 2008 suggest trying to find if its effect on other outcomes justify its re-establishment.

It might be the case that the program is effective in terms of developing new products, whose innovative component is not patented. To find out if this is the case, the set of outcome variables for companies included in the analysis of this paper has been extended to add the response to the question if they introduced new products to the market. This results are in process of elaboration and will shortly be included in an extended version of this paper.

There are other dynamic effects that could be attributed to the program that are not necessarily reflected in the time horizon where we want to measure its impact. A more complete analysis should include them. For example, research and technological development infrastructure projects subsidized under the program might reduce the fixed costs associated to future research and technological development projects.

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