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INTERNATIONAL RESEARCH COLLABORATION, RESEARCH TEAM PERFORMANCE, AND SCIENTIFIC & TECHNOLOGICAL CAPABILITIES IN COLOMBIA --A BOTTOM-UP PERSPECTIVE[1]

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A. Introduction

International research collaboration is a growing social phenomenon (Wagner and Leydesdorff 2006; NSF-NSB 2008). It results in part as a strategy to deal with increasingly complex problems and raising costs of research (Luukkonen, Persson; et al. 1992; Gibbons, Limoges et al. 1994; Adams, Black et al. 2005). It also responds to government policies oriented to favor such behavior (Georghiou 1998; Wagner, Brahmakulam et al. 2001), and to the increased mobility of scientists across borders.

For long time, research collaboration is seen as an important source of creativity (Farrell 2001; Burt 2004; Levine and Moreland 2004; Uzzi and Spiro 2005), which coupled with the right set of conditions, may increase scientific productivity (Beaver and Rosen 1979; Landry, Traore et al. 1996; Adams, Black et al. 2005; Lee and Bozeman 2005; Turner and Mairesse 2005), research quality (Diamond 1985; Katz and Hicks 1997; Basu and Aggarwal 2001; Frenken, Hölzl et al. 2005; Rigby and Edler 2005), and innovative capacity (Allen 1977; Georghiou 1998; Le Bas, Picard et al. 1998; Tsai and Ghoshal 1998; George, Zahra et al. 2002; Landry, Amara et al. 2002; Belderbos, Carree et al. 2004; Granovetter 2005).

Research collaboration is also said to have great potential for the creation of science and technology human capital (Coleman 1988; Rogers 2001; Rogers and Bozeman 2001; Seibert, Kraimer et al. 2001; Bozeman and Rogers 2002; Bozeman and Corley 2004), the consolidation of research agendas, and the expansion of research areas.

There is, however, extant literature warning about the negative impacts of research collaboration on almost the same aspects, that is, on productivity (Fox and Faver 1984; Landry and Amara 1998; Carayol and Matt 2004b; Cummings and Kiesler 2005); output quality (Herbertz 1995; Kleinman 1998); innovative capacity (Gelijns and Thier 2002); human capital (Behrens and Gray 2001; Stephan 2001; Slaughter, Campbell et al. 2002); and relevance of the research (Kleinman 1998; Florida 1999; Sagasti 2004; Shrum 2005). Risks and costs identified include the privatization and capture of traditional 'public' knowledge, the 'mercantilization' of knowledge and human capital as resulting from public-private research partnerships, and crowding out effects.

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Besides the effects regarding research collaboration, international research collaboration can give developing countries access to new knowledge and research resources they would not have otherwise (Wagner, Brahmakulam et al. 2001). It may raise the quality of the research performed in those countries, increasing the possibility for local scientists and engineers to benefit from the expertise brought about by international partners.

However, international research collaboration can also increase their loss of autonomy or freedom (Cozzens, Gatchair et al. 2008) and 'distract' local capabilities and critical mass needed to face local concerns forcing them to address 'irrelevant' issues (Sagasti 2004).

On the other hand, the social organization of scientists into teams is today an incontestable characteristic of most national science and technology systems (Gibbons, Limoges et al. 1994; Etzkowitz and Kemelgor 1998; Laredo 2003). Both developed and developing ones. One key assumption of this work is that research teams are both indicators and multipliers of local S&T capacities, and in so being, they are vehicles of S&T progress. Although rarely explicitly acknowledged in the public policy literature, this is what makes research teams an appropriate unit of analysis and focus of research and innovation policy (Laredo and Mustar 2001). In fact, whereas the process of institutionalization of S&T as an indicator of local capacity has been implicitly recognized (Beaver and Rosen 1979; Gibbons, Limoges et al. 1994; Crow and Bozeman 1998; Etzkowitz and Kemelgor 1998; Etzkowitz and Leydesdorff 2000), their regard as 'multiplier devices' or vehicles through which S&T capacities are created is still underdeveloped (Andrews 1979; Beaver and Rosen 1979).

This dissertation attempts to contribute to current knowledge and understanding of the extent, characteristics, and potential ways international research collaboration, a rather unexplored phenomenon, affects S&T capabilities in the context of a developing country. More precisely, the purpose of this research is to explore the ways international research collaboration can affect local scientific and technological capabilities as reflected by the performance of research teams in Colombia.

In this framework, a research team is defined as two or more individuals who claim they work together on common research problems or interests; are recognized by their institution of affiliation and by the Colombian Institute for the Development of Science and Technology (Colciencias) as such; and produce research outputs jointly or independently.

S&T capabilities are measured by the productivity of the teams in terms of their bibliographic production and their revealed capability to contribute to local knowledge.

Mediating factors such as team characteristics, partner characteristics, scientific discipline, sector, location, and characteristics of the teams' home institution are analyzed to better understand the ways international research collaboration affects research team productivity and their contribution to local knowledge in Colombia.

International research collaboration is measured in three ways: co-authorship, researchers working at local research teams, and foreign funding. While team productivity is measured by their bibliographic production, that is, their writing of journal articles, books, book chapters, working papers, etc. (19 types of scientific products), team contribution to local knowledge is measured by the extent to which the team works on issues involving 'Colombia', which is observed in the titles of their R&D projects or their products or in the corresponding abstracts.

To account for the effects of international research collaboration on research team productive capacity, several research hypotheses are tested using zero-inflated negative binomial regression models to predict counts of a highly skewed distribution. To account for the effects of international research collaboration on research team ability to contribute to local knowledge, research hypotheses are tested using logistic regressions.

Both the impact of different types of collaboration and different types of partners (North and South) are investigated. The propensity score matching approach is used to assess the impact of international research collaboration on team performance using control groups while controlling for selection bias.

The analyses are done on cross sectional data of 1889 Colombian research teams active between 2003 and 2005 working in all scientific fields, and on a sample of 672 teams. In addition, 20 interviews done to team members provide qualitative information needed to interpret the findings and its implications.

B. Methodology

The analysis of the effects of international research collaboration on team productive capacity is based on the testing of the following research hypotheses:

H1. International research collaboration (IRC) positively affects team productivity in Colombia. This hypothesis is grounded on the literature that claims that research collaboration facilitates access to materials, financial resources, new knowledge, and relevant information, and that by so doing it increases creativity and productivity. This is the "more-is-better argument."

H2 and H3. Receiving foreign funds to support R&D activities or co-authoring with foreign partners located overseas increase overall team productive capacity. The reason supporting this hypothesis is apparent as co-authorship and foreign funding usually imply the elaboration of research products. For our purposes this is the "linear-model argument."

H4. Hosting foreign researchers reduces team productive capacity. This hypothesis is based on the "transaction costs argument."

H5. Teams that collaborate with partners from the North have more bibliographic products. This hypothesis is based on the "diversity argument."

H6. Working with projects funded by foreign institutions increases team productive capacity more for teams that collaborate with northern countries than for those that collaborate with partners from the south. This implies the combination of two positive effects: the effects derived from working in projects with foreign funding (the linear model argument) and the effects derived from the "diversity argument."

The analysis of the effects of international research collaboration on team ability to contribute to local knowledge is based on the testing of the following research hypotheses:

H7. Teams that collaborate internationally are less likely to use 'Colombia' in their research activities. This hypothesis is based on the "dependency argument."

H8 and H9. Co-authoring with foreign partners located overseas or receiving foreign funding reduce the probability of teams to work on research activities involving 'Colombia'. This hypothesis is based on the "outsourcing-or-opportunity argument."

H10. Hosting foreign researchers increase the probability of teams to involve 'Colombia' in their research. This is based on the "commitment argument."

H11. Teams that collaborate with partners from the South are more likely to use 'Colombia' in their research projects and products. This hypothesis is based on the "similarity argument."

H12. Working in projects funded by foreign institutions decreases the probability of using Colombia in their research more for teams that collaborate with northern countries than for those that collaborate with partners from the south. This implies the combination of the two effects

discussed earlier: the negative effects derived from working on projects with foreign funding, and the negative effects derived from the "outsourcing argument."

The hypotheses stated are tested using the following models:

Zinb totbibprod05 = a + β1IRC05 + β2Core03 + β3age03 + β4totphds03 + β5totprojects03 + β6agroscs + β7medscs + β8social + β9human + β10engi + β11othscs + β12bussector + β13govsector + β14othsector + β15medinst + β16smallinst + β17smallcity + β18medcity

where team productive capacity is measured by the total number of bibliographic products done between 2003 and 2005, "totbibprod05," and the independent variable, international research collaboration, is represented by a dummy variable, "IRC05," coded 1 if the team had foreign researchers and/or foreign funding between 2003 and 2005, zero otherwise. Team size, "Core03," is an interval-level variable for the number of researchers and technicians the team had in 2003. Team age, "age03," is an interval-level variable for how long the team had been in existence in 2003. The total number of PhDs, "totphds03," is represented by an interval-level variable for the number of members with PhD degree the team had in 2003. Team dynamism is measured by an interval-level variable, "totprojects03," for the number of R&D projects the team had active in 2003. Scientific field is represented by six dummy variables, with teams working in the natural sciences as the reference group. Sector is represented by three dummy variables, with teams working in the academic sector as the reference group. Size of the home institution is represented by two dummy variables, with teams affiliated with big institutions as the reference group. City-size is represented by two dummy variables, with teams located in big cities as the reference group.

And:

Logit ppkeycol05= a + *β1*IRC05 + *β2toβ5team characteristics03* + *β6toβ9*Field + *β10toβ12Sector + β13andβ14institusize + β14andβ15location*

where team ability to contribute to local knowledge is measured as a dummy variable, "ppkeycol05" coded 1 if the team used 'Colombia' in the title of an R&D project or product or in the corresponding abstract, 0 otherwise. The independent and control variables are measured the same way as in the previous model.

The zero-inflated negative binomial model (ZINB) and the logistic model (Logit) are used given the characteristics of the dependent variables and their distribution. These models were implemented following Long and Freese 2001 and Lewis 2003, respectively (Long and Freese 2001; Lewis 2003)

The Propensity Score Matching approach was used to assess the impact of international research collaboration on team performance by using counterfactuals. This approach was implemented following Caliendo and Kopeining 2008 (Caliendo and Kopeining 2008).

The analyses are based on two databases built from three data sources. The first database contains information on teams' characteristics and activities for 1889 teams of more than two members and at least one R&D project active between 2003 and 2005. This database supports most of the analysis done to explain the effects of hosting foreign funding and of working with foreign funding on team performance. The second database is a random sample of 672 teams extracted from the former database, which excludes teams working in the social sciences and the humanities. This database supports the analysis done to explain the effects of co-authoring with partners located overseas on the performance of Colombian research teams. The data sources used

to build these datasets are CvLAC, GrupLAc[3], and a query to the Web of Science retrieving the references of 5491 journal articles published between 1998 and 2005 in all fields by researchers located in Colombia. Table 1 shows the characteristics of the variables used and how the three data sources were used to construct the two databases that support the analyses done.

Table 1: Variables and Data Sources

Dependent and Independent Variables and Data Sources*

	Variable	Type of Variable			Data Source		
		Count	Interval	Dummy	GrupLAC	CVLAc	WOS
Dependent Vars.	Bibliographic Products	x			x		
	Keyword Colombia			x	x		x
Research Team Characteristics.	Team Size		x		x		
	Team Age		x		x		
	Researchers with PhD	x				x	
	Leader Studied Overseas**			x		x	
	Leader Speaks Other Language **			x		x	
	R&D Projects active		x		x		
Scientific Filed	Team 1st. Scientific Field			6x	x		
Home Institution	Sector of Operation			4x	x		
	R&D Size of Institution of Affiliation			3x	x		
Localization	CitySize of Team			3x	x		
IRC	Co-Authorship with Internat Partner ***			x			x
	Foreigners in Teams			x		x	
	International Funding			x		x	
Partner Charac.	Location of Partner****			2x			x

* Cross Sectional Data observed for the period 2003-2005
** Used for predicting International Research Collaboration only
*** Observed for 1998-2005 and for 2001 and 2002 only
**** Used for those who collaborated internationally only

C. Findings

1. International Research Collaboration and Team Productive Capacity

The following are the results obtained so far regarding the determinants of research team productive capacity and the effects of international research collaboration on such capacity:

Teams that collaborate internationally, that are large in size, with many years of experience, that have many PhDs, and that report many projects active, tend to be more productive than comparable teams that do not collaborate internationally, that are of a small size, that were created recently, that have few or no PhD members, and that report few projects active.

Teams working in the humanities are less productive than comparable teams working in the natural sciences. Teams affiliated with small institutions are less productive than comparable teams affiliated with big institutions.

Regarding the probability of being in the unproductive group of teams (called the "always-0 group"), collaborating internationally or having many research projects active reduce the odds of reporting no bibliographic products. In contrast, large teams, old teams, teams working in the medical sciences, and teams affiliated with the business or the government sector, are more likely than comparable teams of smaller size, younger teams, teams working in the natural sciences, and teams affiliated with the academic sector to be in the always-0 group of non-productive teams.

[3] These data sources are administered by Colciencias, the Colombian science and technology funding organization. See www.colciencias.gov.co Look for the 'Scienti Platform' link in the institution's main webpage to access the information.

As shown in Table 2, and looking at the variables with statistically significant effects on team productivity, one finds that the expected rate of bibliographic products for collaborating teams are 36% as high as that of non-collaborating teams, and that collaborating teams are 56% less likely of being in the always zero group of unproductive teams than comparable teams that do not collaborate internationally.

International research collaboration is the explanatory variable with the greatest impact on team productivity right after the number of R&D projects active and the number of PhDs a team has. In fact, a one standard deviation increase in international collaboration increases team's expected productivity count by 16%, holding the other variables constant (the effects of number of projects active and of members with PhDs are 34% and 18% respectively). Measured in terms of discrete changes (not shown here), and holding all other variables constant at their means, collaborating internationally increases expected productivity count by 3.14 bibliographic products.

On the other hand, an additional team member increases the expected team's rate of bibliographic products by 2.5%, but an additional team member increases team's odds of being in the always zero group by 5%, holding all other variables constant.

Table 2: Team Productive Capacity: Percentage Change in Expected Count

	Tot. Bib. Prods. 2003-5*		Always0**	
	%	%StdX	%	%StdX
Internat. Res. Coll.	35.6	16	-56.1	-33.1
Team size in 2003	2.5	14.9	5.3	34.6
Team Age in 2003	1.1	6.6	4.1	26.7
Total PhDs in 2003	7.8	18	-7.2	-15.3
Tot. Proj. in 2003	4.5	33.7	-6.2	-34.6
Agrosciences	-9.3	-2.3	119.4	20.7
Medical Sciences	2.8	0.9	127.5	31.4
Social Sciences	0.3	0.1	74.9	22.9
Humanities	-16.6	-7.5	33.4	13.1
Engineering	1.7	0.6	24.1	7.6
Other Sciences	-15.5	-3.3	19.5	3.7
Business Sector	-31.8	-6.7	231.2	24.2
Government	22.8	4	251.1	27.4
Other Sector	35	4.4	78.4	8.6
Mid. Home Inst.	3.7	1.8	-31.2	-16.6
Small Home Inst.	-23.5	-9.5	-28	-11.5
Small City	14	1.7	68.3	7.1
Midsize City	-13	-5.6	-30.4	-13.9
ln alpha	-0.02030			
alpha	0.97990	SE(alpha) = 0.06100		

% = percent change in expected count for unit increase in X

%StdX = percent change in expected count for SD increase in X

* Count Equation: Percentage Change in Expected Count for Those Not Always 0

** Binary Equation: Factor Change in Odds of Always 0

An additional year of team age increases team productivity by 1.1%, and its odds of being in the non-productive teams by 4%, holding the other variables constant.

An additional PhD member increases team's expected bibliographic production by 8%, holding all other factors constant.

Each additional R&D project active increases team's expected rate of bibliographic products by 4.5% and decreases its odds of being in the always-0 group by 6%, holding the other factors constant.

Teams working in medical sciences have similar expected rate of production of comparable teams working in the natural sciences. However, the former type of teams is 2.28 times more likely of being in the unproductive group of teams than those working in the natural sciences, holding the other factors constant.

The expected rate of production of teams working in the humanities is 17% lower compared to similar teams working in the natural sciences.

As one would expect, teams affiliated with the business sector as compared to teams affiliated with the academic sector are less productive and more likely of not having the opportunity to report bibliographic products by a factor of 3.31, holding all other factors constant.

Teams affiliated with the government sector as compared to teams affiliated with institutions working in the academic sector do not have different expected rate of production, holding the other variables constant. However, teams working at government institutions are 3.51 times more likely than comparable teams affiliated with the education sector of not having the opportunity to report bibliographic products.

Teams affiliated with small institutions are 23.5% less productive than teams affiliated with big institutions, holding all other variables constant.

Finally, based on the model analyzed, the size of the urban agglomerate where the team is located seems to weakly affect its productive capacity once we hold the other variables constant. Teams located in mid-size cities are less productive than comparable teams located in large cities. This finding is statistically significant at the 0.6 level, however.

Wald Tests (not shown here) performed on the joint effects of the discipline variables, the variables related to the characteristics of the institution of affiliation, and the sector variables show evidence that, at conventional statistical levels of 0.1, 0.05, and 0.01, all these factors help to explain team bibliographic production, holding the other variables constant. Based on these tests, there is a 10%, 1% and 0.1% probability that the effects observed of scientific discipline, size of institution and sector on team productivity could respectively have occurred by chance. In addition, this is consistent with the literature reviewed; therefore we can confidently keep these variables in the model for further analyses.

A different conclusion is drawn regarding the joint effects of team location on team productivity. Based on the Wald Test on these variables, and holding all other variables constant, there is a 20% probability that the observed results could have occurred by chance (Prob > chi2 = 0.1972).

We are interested not only in understanding the effect of international research collaboration on team performance but also on the way other factors also explain team productive capacity depending on their collaboration status (Lewis 2002). For example, it is possible that the effect of team size or of number of PhD holders on team productivity vary by collaboration status. To allow this possibility, interaction terms were added to the model without the location variables.

Thus, according to the results not shown here, collaborating teams with their most basic characteristics, that is, with two members, less than a year old, with no PhD holders, and one project active are more productive than non-collaborating teams of comparable characteristics.

Holding all other variables constant, as team size increases by one, team scientific productivity increases by 4.5% among non-collaborating teams, and, interestingly, it increases team productive capacity more among the non-collaborating teams than among collaborating teams of comparable characteristics. This finding suggests that there might be substitution effects between team size and international research collaboration in place. That is, the effects of having a small team can be compensated by the effects of collaborating internationally, and inversely, the effects of no collaborating internationally can be compensated by raising the size of teams.

Significant interacting effects were found between international research collaboration and size of home institution in the case of teams affiliated with small institutions. In fact, collaborating teams affiliated with small institutions are more productive than comparable non-collaborating teams affiliated with small institutions.

Similarly, interacting effects were found to be statistically significant regarding scientific discipline in the case of teams working in the multidisciplinary sciences. In fact, collaborating teams working in the multidisciplinary sciences are more productive than non-collaborating teams working in the same science and with similar characteristics. Moreover, the effects or collaborating internationally are greater among teams working in the multidisciplinary sciences than among teams working in the natural sciences.

The results show that there are no significant interacting effects between international research collaboration and sector.

The comparison of the models with and without the interaction terms using an LR Chi2 test shows that the improvement obtained by adding the interaction terms (33.16) is statistically significant as it is greater than the critical value of the chi-square distribution for 12 degrees of freedom at the 0.01 level (26.22).

But an even better method for assessing the impact of international research collaboration on research team performance is by comparing teams of similar characteristics in all relevant aspects and, in particular, on the probability of collaborating internationally. In fact, collaborating teams may be more productive for the same reasons they collaborate internationally. In other words, foreign partners may prefer to collaborate with those teams and in those R&D projects that are expected to generate new knowledge and outputs. This is technically called ‘endogeneity’ or reverse causality, and it may result from selection bias. Hence, to estimate the “real” effect of international research collaboration, it is necessary to address the basic question: How would the teams collaborating internationally have performed had they not participated in a collaborative experience with international partners? To the author’s knowledge, no study on the impact of research collaboration (whether local or international) has attempted to model this counterfactual situation.

To solve this endogeneity problem, comparable groups both in terms of their internal characteristics and particularly in their propensity to collaborate internationally were used following the Propensity Score Matching Approach.

Although the set of variables used in the model analyzed clearly satisfy the Conditional Independence Assumption (CIA) required for the approach to be accurate (Caliendo and Kopeining 2008) as the set of observable covariates are not affected by treatment (international collaboration), and therefore potential outcomes are independent of treatment assignment, two new variables are added to better account for the determinants of international research

collaboration: a) a dummy variable coded 1 if the team leader writes well in a second language, 0 otherwise; and b) a dummy variable coded 1 if the team leader studied overseas, 0 otherwise.

To contrast the productivity of a collaborating team with productivities of comparison group teams, the kernel matching algorithm is used.

The STATA module developed by Leuven and Sianesi (2003) is used to estimate the full model and test the balancing hypothesis using an iterative process to ensure that the estimated model is consistent with this requirement (Leuven and Sianesi 2003). Thus, the average treatment effects on the treated yields a difference of 4.24 bibliographic products in favor of those teams of similar characteristics and probabilities to collaborate internationally that did collaborated versus those that did not. A difference of 4.24 is significantly large even in the most conservative scenario of a bandwidth of 0.01. If we increase the bandwidth to 0.05 and 0.1 (not shown here), the difference in productivity between collaborating and non-collaborating reaches 4.47 and 4.86 products respectively, a statistic far from the 7.89 reported by a simple t-test model based on the unmatched sample, but still an important difference[4].

To assess the matching quality Table 3 below shows that we significantly reduced the differences between the characteristics on the teams with the matching procedure, turning the treated and the control groups significantly similar, which makes them comparable in all relevant aspects. For example, the difference in the number of PhD holders between teams that collaborated versus those that did not falls substantially from 1.55 to 0.05 once we used the matched teams, reducing the bias 96.7%. A 98.9% reduction of the bias is achieved by the matching procedure regarding the difference in team size between collaborating and non-collaborating teams: the difference of 2.97 members between unmatched teams falls to 0.03 between matched teams.

[4] After imposing the common support condition, 19 of the 736 teams that collaborated internationally fell outside the common support region because their propensity score was higher than the maximum propensity score of the non-collaborating teams. Hence, these 19 cases were discarded, and the analyses of the average treatment effect (ATE) and of the average treatment effect of the untreated (ATU) are done on 1,843 teams out of the 1,889 teams of the sample.

Table 3: Assessment of the Matching Quality: PSM-Research Team Productive Capacity

Variable	Sample	Mean Treated	Mean Control	%bias	%reduct bias
Internat. Res. Coll.	Unmatched	1	0	.	
	Matched	1	0	.	.
Team size in 2003	Unmatched	9.072	6.1006	50.7	
	Matched	8.5007	8.4679	0.6	98.9
Team Age in 2003	Unmatched	8.8478	5.6644	54	
	Matched	8.5635	8.8296	-4.5	91.6
Total PhDs in 2003	Unmatched	2.4035	0.84996	69.1	
	Matched	2.1841	2.1333	2.3	96.7
Leader Writes in Other Lang.	Unmatched	0.70245	0.4484	53.2	
	Matched	0.70014	0.714	-2.9	94.5
Leader Studied Overseas	Unmatched	0.66712	0.48222	38	
	Matched	0.66109	0.66497	-0.8	97.9
Tot. Proj. in 2003	Unmatched	8.2215	4.1752	59.6	
	Matched	7.4435	7.2547	2.8	95.3
Agrosciences	Unmatched	0.06386	0.05898	2	
	Matched	0.06276	0.07111	-3.5	-71
Medical Sciences	Unmatched	0.13315	0.12229	3.3	
	Matched	0.12971	0.11316	5	-52.3
Social Sciences	Unmatched	0.11821	0.18907	-19.7	
	Matched	0.12134	0.11393	2.1	89.5
Humanities	Unmatched	0.22283	0.25412	-7.3	
	Matched	0.22315	0.2115	2.7	62.8
Engineering	Unmatched	0.11821	0.14397	-7.6	
	Matched	0.11994	0.13507	-4.5	41.3
Other Sciences	Unmatched	0.04755	0.03903	4.2	
	Matched	0.04324	0.04067	1.3	70
Business Sector	Unmatched	0.0394	0.03036	4.9	
	Matched	0.03626	0.05325	-9.3	-87.7
Government	Unmatched	0.04348	0.03556	4.1	
	Matched	0.04324	0.0483	-2.6	36.1
Other Sector	Unmatched	0.03261	0.01301	13.1	
	Matched	0.03208	0.02442	5.1	60.9
Mid. Home Inst.	Unmatched	0.2894	0.43539	-30.7	
	Matched	0.29289	0.28148	2.4	92.2
Small Home Inst.	Unmatched	0.1413	0.18474	-11.8	
	Matched	0.13947	0.13483	1.3	89.3
Small City	Unmatched	0.00543	0.02515	-16.1	
	Matched	0.00558	0.00302	2.1	87
Midsize City	Unmatched	0.1644	0.25412	-22.2	
	Matched	0.16318	0.1717	-2.1	90.5

A bootstrapping procedure was used to test the statistical significance of treatment effects and to compute their standard errors in case analytical estimates are biased or unavailable. Each bootstrap draw consisted in the re-estimation of the results, including the estimation of propensity scores, common support, etc. The bootstrapping was repeated 999 times, which led to 999 bootstrap samples and 999 estimated average treatment effects. Based on the bootstrap results obtained (observed coefficient = 4.24, z = 3.89, P>|z| = 0.000), we confirm our finding and confidently conclude that *international research collaboration is a strong factor affecting research team productivity in Colombia.* This finding supports our first hypothesis based on the "more-is better argument."

To better understand the effect of international research collaboration, similar analyses were done regarding the effects of different types of collaboration and different types of partners. The following are the findings obtained so far:

Type of collaboration affects team productivity in different ways, however. As shown in Table 4, while hosting foreign researchers is not statistically associated with team productivity, leveraging foreign funding or co-authoring with partners located overseas increase team productivity by nearly 40%, and between 6.5 and 7.4 bibliographic products if the teams work in projects with foreign funding, and by between 4.4 and 5.3 bibliographic products if someone from the team co-authors with a colleague located in another country.

The effects of international research collaboration on team productivity also depend on the type of partner the team collaborates with. Thus, teams collaborating with partners from the south are 46% more productive than comparable teams not collaborating with partners from the south. In fact, teams collaborating with the south produce between 4.9 and 7 bibliographic products.

The effects of collaborating with partners from the north are smaller. In fact, teams collaborating with this type of partners are 18% more productive than teams not collaborating with partners from the north. They produce between 4 and 4.8 bibliographic products.

More interestingly, as the table shows, different combinations of type of collaboration and origin also yield different effects on team productive capacity. Hence, funding form southern countries appears contributing more on team productivity than funding from northern countries and than hosting foreign researchers from southern countries. Hosting researchers from northern countries does not seem to be associated with team productive capacity in Colombia.

Table 4: Impacts of Different Type of Collaboration and Partner on Team Productive Capacity: ZINB and PSM

	ZINB			PSM					
	%	Count	P>|z|	A	T-stat	B	T-stat	C	T-stat
Internat. Res. Coll.	36	3.14	0.000	4.24	5.28	4.47	5.69	4.86	6.34
Foreign Researchers	13	0.1	0.069	-0.79	-0.97	-1.13	-0.16	0.85	1.11
Foreign Funding	41	3.93	0.000	6.48	6.31	6.93	6.89	7.4	7.52
Co-Authorship *	39	2.91	0.013	4.43	2.37	4.68	2.64	5.31	3.07
Int. Res. with North	18	2.13	0.011	4.03	4.28	4.31	4.72	4.78	5.41
Int. Res. with South	46	3.48	0.000	4.88	4.17	5.81	5.06	7.05	6.20
People from North	-7	-0.25	0.415	-1.07	-1.09	-0.28	-0.29	0.87	0.96
People from South	31	1.96	0.002	0.82	0.82	2.06	2.11	2.81	2.9
Funding from North	28	2.86	0.000	6.07	5.56	6.28	5.95	6.85	6.62
Funding from South	53	5.30	0.000	10.98	4.82	12.61	5.60	14.35	6.40

Observations: 1889

* Analysis done on 672 Teams
A: ATT with bandwidth of 0.01
B: ATT with bandwidth of 0.05
C: ATT with bandwidth of 0.1

Next section discusses on the effects of international research collaboration on team orientation in Colombia.

2. International Research Collaboration and Team Ability to Contribute to Local Knowledge

Collaborating teams were more likely to use 'Colombia' in their projects and products than non-collaborating teams: while 47% of the teams that collaborated internationally used Colombia in their projects or bibliographic products, only 29% of the teams that did not collaborate internationally used the country as the unit of analysis or object of their research processes. This accounts for a difference of around 17% in the odds of involving 'Colombia' between collaborating and non-collaborating teams. A t-test shows that this finding is significant at the 0.01 level. But, how much of that effect is caused by the collaborative behavior alone? How do other factors influence team probability of using Colombia in their research?

To answer these questions, a logit model that takes into account the characteristics of the outcome variable investigated, the independent variables of interest, and the control variables found in the literature to have a significant effect on team performance was used. The overall impact of international research collaboration on team's ability to contribute to local knowledge is assessed using control groups based on the Propensity Score Matching approach.

The following are the results obtained so far regarding the determinants of research team ability to contribute to local knowledge and the effects of international research collaboration on such ability:

Collaborating internationally, having many projects active, working in the social sciences, or working in the NGOs' sector increase team's odds of working in projects or products that use Colombia in their research as compared to those of similar characteristics that do not collaborate internationally, have fewer projects active, work in the natural sciences, or work in the academic sector.

Teams working in the engineering or in small institutions are less likely of working in projects or products that use 'Colombia' than comparable teams working in the natural sciences or in large institutions.

These finding are statistically significant at conventional levels. However, team size, team age, team education, and team location do not seem to have a significant explanatory power of team contribution to local knowledge, once we hold all other variables constant. In fact, a Wald Test of the joint effects of team localization reveals that there is a 30% probability that the observed results could have occurred by chance (Prob > chi2 = 0.2957).

Hence, based on the model without the location variables shown in Table 5, and holding all other variables constant, the odds of a team working in research involving 'Colombia' are 1.56 times larger for collaborating teams than for non-collaborating teams. In fact, holding all other variables constant at their means (not shown here), collaborating internationally increases team's probability of contributing to local knowledge by 10.3%.

For each additional project active, team's odds of contributing to local knowledge increase by 9%, holding the other variables constant. The odds of working in research projects or producing bibliographic products that use 'Colombia' are 2.12 times larger among teams working in the social sciences than among comparable teams working in the natural sciences. By contrast, the odds of involving Colombia in the research process are 50% lower for teams working in the

engineering areas than for those of comparable characteristics working in the natural sciences. The odds of working on projects or products involving Colombia of a team affiliated with the NGO's sector are 2.9 times larger compared to those of similar teams affiliated with the academic sector. Finally, the odds of using 'Colombia' in the research process of a team affiliated with a small institution are 37% lower compared to those of comparable teams affiliated with large institutions.

Table 5: Team Contribution to Local Knowledge: Percentage Change in Odds

	'Colombia' in Prod or Proj	
	%	%StdX
Internat. Res. Coll.	56.2	24.3
Team size in 2003	0.3	2
Team Age in 2003	-0.5	-2.8
Total PhDs in 2003	1.1	2.5
Tot. Proj. in 2003	8.9	75.7
Agrosciences	21.5	4.8
Medical Sciences	6.4	2.1
Social Sciences	112.5	32
Humanities	12.5	5.2
Engineering	-49.8	-20.9
Other Sciences	30.3	5.5
Business Sector	0.7	0.1
Government	70.7	10.9
Other Sector	190.4	16.4
Mid. Home Inst.	-10.3	-5.1
Small Home Inst.	-36.5	-15.6

b = raw coefficient
z = z-score for test of b=0
P>|z| = p-value for z-test
% = percent change in odds for unit increase in X
%StdX = percent change in odds for SD increase in X
SDofX = standard deviation of X

To better assess the effects of international collaboration on team's research orientation, control groups created using the Propensity Score Matching approach are used. The analysis is done based on the full model including the location variables and the characteristics of the team's leader as before.

Using a bandwidth of 0.01, the average treatment effect on the treated yields a difference of 9% in the odds of contributing to local knowledge in favor of those teams that collaborate internationally over those that do not. This difference in the odds is smaller to the one observed comparing collaborating and non-collaborating teams using an unmatched sample (17.3%), but it remains significant after the matching algorithm is applied.

A test of the accuracy of the matching procedure shows the improvement of the model: the differences in the characteristics become statistically insignificant in the matched sample (not shown here). Based on the bootstrapping performed through the re-estimation of the results 999 times to test the statistical significance of the findings, we can confidently conclude that

international research collaboration positively affects team contribution to local knowledge. This finding is significant at the 0.01 level (Observed Coefficient = .0900353, z = 2.74, and P>|z| = 0.006). This finding does not support our eighth hypothesis based on the "dependency argument."

Similar analyses were done to observe the effects of different types of collaboration and different types of partners on research team ability to contribute to local knowledge. The following are the findings obtained so far:

Co-authoring with partners located overseas appears as the type of collaboration with the greatest impact on team's ability to contribute to local knowledge. In contrast, and similar to the factors affecting research team productive capacity, hosting foreign researchers does not seem to have a significant effect on team research orientation.

Contrary to the findings regarding the effects of collaborating with partners from the South on research team productive capacity, in this case collaborating with such partners is not significantly associated with team contribution to local knowledge.

Finally, working with projects funded by northern countries appears to have the greatest effect on team contribution to local knowledge, followed by the effects of working with projects funded by partners from southern countries. Table 6 summarizes these findings.

Table 6: International Research Collaboration and Team Contribution to Local Knowledge: Logit and PSM

	Logit			PSM (%)					
	% (1)	%(2)	P>|z|	A	T-stat	B	T-stat	C	T-stat
Internat. Res. Coll.	56.2	10.3	0.000	9.0	3.00	9.5	3.29	10.5	3.86
Foreign Researchers	1.6	15.0	0.902	-0.5	-0.17	0.4	0.15	2.2	0.78
Foreign Funding	89.8	0.3	0.000	16.6	4.96	16.2	5.12	17.0	5.65
Co-Authorship *	166.7	11.9	0.000	15.5	3.09	15.5	3.31	16.3	3.58
Int. Res. with North	77.2	13.3	0.000	11.9	3.59	12.8	4.08	13.9	4.72
Int. Res. with South	19.9	4.2	0.203	4.2	1.28	6.7	2.09	9.5	3.03
People from North	14.3	3.1	0.388	2.2	0.61	4.3	1.24	6.7	1.96
People from South	-9.8	-2.3	0.547	-2.4	-0.64	-0.1	-0.04	1.2	0.32
Funding from North	85.3	14.6	0.000	16.1	4.59	16.9	5.19	17.9	5.77
Funding from South	65.9	12.1	0.020	15.4	3.14	20.4	4.34	24.5	5.28

Observations: 1889

* Analysis done on 672 Teams

%(1): Percentage Change in Odds

%(2): Changes in Predicted Probabilities for 'Colombia' in Prod or Proj

A: bandwidth of 0.01; B: bandwidth of 0.05; and C: bandwidth of 0.1

Next section identifies the factors that characterize those teams that collaborate internationally. Since collaborating internationally positively affects team performance, by knowing what factors affect collaboration decisions will help the design of policies oriented at encouraging the internationalization of Colombian R&D teams, and by so doing, Colombian S&T capabilities.

3. Who Collaborates Internationally in Colombia?

As discussed earlier, among the 1889 teams studied 736 collaborated and 1153 did not. What factors explain the collaborative behavior?

To answer to that question the following model is tested using logistic regressions.

$$\Pr(IRC05=1) = F(\beta o + \beta Core03 + \beta age03 + \beta totphds03 + \beta totprojects03 + \beta agroscs + \beta medscs + \beta social + \beta human + \beta engi + \beta othscs + \beta bussector + \beta govsector + \beta othsector + \beta medinst + \beta smallinst + \beta smallcity + \beta medcity)$$

According to the results of the logit model used, as team size, team age, number of members with PhD and number of R&D projects increase, teams' probability of collaborating internationally. Teams led by researchers able to write well in a second language, and teams led by someone who studied overseas in the past, are more likely to collaborate than teams of similar characteristics. Teams working in the medical sciences, the social sciences or in the engineering are less likely to collaborate internationally than comparable teams working in the natural sciences. Teams affiliated with large institutions are more likely to collaborate than comparable teams affiliated with small or mid-size institutions. Finally, teams located in small cities are less likely to collaborate internationally than comparable teams located in big cities. All these statistics are significant at conventional levels.

In contrast, and as a Wald Test of joint effects shows, the sector where the teams work does not appear to significantly affect the probability of collaborating internationally. In fact, there is a 47% probability that the observed results could have occurred by chance. Therefore, we can confidently conclude that the hypothesis that the effects of the sector variables are simultaneously equal to zero cannot be rejected, hence we may drop these variables from the model.

Hence, based on the new model without the sector variables as shown in Table 7, the number of PhDs appears to be the variables with the greatest impact on the probability of collaborating internationally. In fact, a one-unit increase in the number of members with PhD increases the odds of collaborating by 33%, holding the other variables constant, and as the number of team members with PhD increases from 1 to 2 (not shown here), the probability of collaborating internationally increases by 6.6%, holding the other variables constant at their means.

A one-unit increase in team size increases the odds of collaborating internationally by 3.1%, holding the other variables constant, and as the number of team members increases by one unit from 6 to 7 the probability of collaborating increases by 0.7%, holding the other variables constant at their means.

A one-year increase in teams' age increases the odds of collaborating by 5.3%, holding the other variables constant, and as team age increases by one year from 6 to 7 years old the probability of collaborating increases by 1.2 percentage points, holding the other variables constant at their means.

Table 7: Determinants of International Research Collaboration: Percentage Change in Odds

Internat. Res. Coll.	b	z	P>z	%	%StdX	SDofX
Team size in 2003	0.03088	2.281	0.023	3.1	19.3	5.7171
Team Age in 2003	0.05175	4.720	0.000	5.3	35.3	5.8373
Total PhDs in 2003	0.28115	6.933	0.000	32.5	86.2	2.2106
Leader Writes in Other Lang.	0.49352	4.208	0.000	63.8	27.9	0.4979
Leader Studied Overseas	0.4748	4.187	0.000	60.8	26.6	0.4972
Tot. Proj. in 2003	0.07044	5.630	0.000	7.3	59.2	6.6037
Agrosciences	-0.4299	-1.713	0.087	-34.9	-9.8	0.2392
Medical Sciences	-0.49279	-2.530	0.011	-38.9	-15.1	0.3325
Social Sciences	-0.4058	-2.212	0.027	-33.4	-13.9	0.3681
Humanities	-0.17743	-1.124	0.261	-16.3	-7.3	0.4284
Engineering	-0.62866	-3.327	0.001	-46.7	-19.3	0.3407
Other Sciences	-0.13547	-0.466	0.642	-12.7	-2.7	0.2014
Mid. Home Inst.	-0.31472	-2.516	0.012	-27.0	-14.2	0.4851
Small Home Inst.	-0.26188	-1.615	0.106	-23.0	-9.3	0.3738
Small City	-1.09116	-1.929	0.054	-66.4	-13.3	0.1310
Midsize City	-0.23988	-1.726	0.084	-21.3	-9.4	0.4138

The odds that a team led by someone who writes well in a language other than Spanish collaborates are 1.64 times as high as that of teams with leaders who do not write well in a second language, holding the other variables constant. Having leaders who are able to write well in a second language increases the probability of collaborating by 11.6%, holding the other variables constant at their means.

Teams led by someone who studied overseas in the past are more likely to collaborate internationally than comparable teams led by someone who did not studied overseas in the past. Holding the other variables constant, the odds that a team led by someone who studied overseas in the past collaborates are 1.61 as high as that of teams led by people who did not studied overseas in the past, and holding the other variables constant at their means, the former type of teams increases the probability of collaborating internationally by 11.2%.

The odds that a team working in the medical sciences, the social sciences, or the engineering collaborate internationally are 39, 33 and 19 percent lower than that of comparable teams working in the natural sciences, respectively. Working in the medical sciences, the social sciences or the engineering rather than in the natural sciences decreases the probability of collaborating by 11, 9 and 14 percent respectively, holding the other variables constant at their means.

The odds that a team affiliated with mid-size institutions collaborates internationally are 27% lower than that of the teams affiliated with big institutions, holding the other variables constant. Being affiliated with mid-size institutions rather than with big-size institutions decreases the probability of collaborating internationally by 7.4%, holding the other variables constant at their means.

Finally, the odds that a team located in small cities collaborates internationally are 66.4% lower than that of comparable teams located in big cities; and holding the other variables constant

at their means, being located in small cities rather than in big cities decreases the probability of collaborating by 21.3%.

If we add squared terms for team size, team age, total number of PhDs, and total number of projects active to see if there are curvilinear effects of these variables on the outcome variable, we find that team size positively affects the probability of collaborating but at decreasing rate. In fact, holding the other variables constant, the probability of collaborating increases with every additional team member but once the team reaches a size of about 24 members the probability starts to fall at an increasing rate. Similarly, team age increases the probability of collaborating with every additional year until it is about 28 years of old, then it decreases the probability of collaborating at an increasing rate, holding all other variables constant. The number of PhD members also appears to have curvilinear effects. It increases the probability of collaborating internationally, and then it decreases it once it reaches a total of 28, holding the other variables constant. Finally, the number of projects active also increases team probability of collaborating, but once it reaches a total of 45 projects, it starts the decrease it at an increasing rate, holding all other variables constant. All these top numbers are within the data range.

These finding seem plausible. As more members are associated with teams, more collaboration with foreign partners is expected. But when the team is too large, international collaboration may be unnecessary. Similarly, once a team reaches a certain level of maturity, and therefore works in a closed niche and benefits from stable institutional support, it may perceive the international collaboration unnecessary. Same 'saturation' effects may also explain the effects of the number of PhDs a team has and the number of its projects active.

An LR test shows that the new model is better than the previous one as the value we get from the difference between the two LR chi2 tests is greater than the critical value for the chi-squared distribution with 2 degrees of freedom at the 0.01 level. That is, we find a statistically significant improvement using the new model.

In sum, based on the results obtained, team size, team age, team composition, leadership, discipline, institution of affiliation, and geographical location seem to affect the probability of collaborating internationally. In contrast, the sector where the team works is not significantly associated with the collaborative behavior.

Finally, team size, team age, number of PhDs and number of projects active increase the probability of collaborating internationally at a decreasing rate. Once they reach a top level the probability of collaborating decreases at an increasing rate.

Similar analyses were done to account for the determinants of each type of collaboration and partners. The following are the findings obtained so far?

Based on the population data, and as Table 8 shows, team size, number of PhDs, the characteristics of the team leader, the scientific discipline in which the team works, and the size of the city in which the team is located affect the choice of hosting foreign funding. On the other hand, all the factors considered except team size and the size of the city where the team is located affect the choice of working with foreign funding (these are confirmed by a Wald Test of the joint effects of the location variables not shown here).

More precisely, larger teams tend to host more foreign researchers than smaller teams of similar characteristics, but the size of the teams does not seem to affect the probability of working with foreign funding.

Older teams tend to prefer working with foreign funding than younger teams, but team age is not associated with the choice of hosting foreign researchers.

The number of PhDs is positively associated with both types of collaboration. Teams led by researchers able to write well in a second language or that studied overseas are more likely to collaborate internationally both through hosting foreign researchers and working with foreign funding than comparable teams.

The number of projects active a team has is associated with the probability of working with foreign funding, but it is not significantly associated with hosting foreign researchers.

Teams working in the medical sciences or in the engineering are less likely to host foreign researchers than comparable teams working in the natural sciences. Teams working in the humanities are less likely to work with foreign funding than similar teams working in the natural sciences.

Teams working in the government sector or in the NGOs' sector are more likely to work with foreign funding than comparable teams affiliated with the academic sector. However, the sector where the team works does not seem to be associated with the probability of hosting foreign researchers.

Teams affiliated with large institutions are more likely to work with foreign funding than comparable teams affiliated with small and mid size institutions, but the size of the home institution does not seem to be significantly associated with the probability of hosting foreign researchers.

Finally, the size of the city where the team is located also seems to affect the choice of hosting foreign researcher as opposed to the choice of working with foreign funding. In fact, teams located in mid-size cities are less likely to host foreign researchers than comparable teams located in large cities.

Table 8: Factors Explaining the Choice of Hosting Foreign Researchers and Working with Foreign Funding

	Foreign Researchers	Foreign Funding
Team Size in 2003	0.048**	-0.004
	(3.67)	(0.28)
Team Age in 2003	0.007	0.052**
	(0.61)	(4.73)
Total PhDs in 2003	0.189**	0.208**
	(5.28)	(5.57)
Leader Writes Oth Langua	0.468**	0.486**
	(3.47)	(3.57)
Leader Studied Overseas	0.344**	0.433**
	(2.69)	(3.33)
Tot. Proj. in 2003	-0.017	0.085**
	(1.64)	(6.97)
Agrosciences	-0.487	-0.303
	(1.70)	(1.10)
Medical Sciences	-0.788**	-0.002
	(3.47)	(0.01)
Social Sciences	-0.413*	-0.224
	(1.99)	(1.08)
Humanities	0.076	-0.433*

	(0.45)	(2.39)
Engineering	-0.714**	-0.306
	(3.29)	(1.50)
Other Sciences	-0.284	0.337
	(0.91)	(1.10)
Business Sector	0.177	0.215
	(0.47)	(0.52)
Government	-0.322	0.693*
	(0.89)	(2.22)
Other Sector	-0.100	1.740**
	(0.22)	(3.92)
Mid. Home Inst.	-0.266	-0.503**
	(1.85)	(3.48)
Small Home Inst.	-0.084	-0.847**
	(0.39)	(3.42)
Small City	-1.865	-0.121
	(1.82)	(0.21)
Midsize City	-0.391*	-0.021
	(2.34)	(0.13)
Constant	-1.959**	-2.453**
	(9.30)	(11.24)
Observations	1889	1889

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

The analysis of the factors affecting the choice of co-authoring with partners located overseas is done using the sample. In this case, the internal characteristics of the teams are excluded as they were observed after the co-authorship took place.

Hence, as shown in Table 9, teams working in the agricultural sciences or the engineering appear less likely to co-author with colleagues located overseas than comparable teams working in the natural sciences.

Interestingly, teams working in the academic sector are less likely to co-author with colleagues located in foreign countries than comparable teams working in the business sector or in the government sector. This may suggest an important level of endogamy characteristic of the Colombian academic sector.

Finally, teams affiliated with large institutions are more likely to co-author with partners located overseas than comparable teams affiliated with the small and midsize institutions. No significant effect of location is found. This is confirmed by a Wald Test of the joint effect of these variables not shown here.

Table 9: Factors Explaining the Choice of Co-authoring with Partners Located Overseas

	Int. Co-Authorship in 2001-2
Agrosciences	-1.050**
	(2.69)
Medical Sciences	-0.322
	(1.25)
Engineering	-0.679**
	(2.59)
Other Sciences	-1.464
	(1.93)
Business Sector	2.325**
	(3.78)
Government	2.154**
	(4.66)
Other Sector	2.366*
	(2.40)
Mid. Home Inst.	-0.921**
	(3.82)
Small Home Inst.	-2.917**
	(5.19)
Small City	-0.468
	(0.59)
Midsize City	-0.403
	(1.54)
Constant	-0.392*
	(2.49)
Observations	672

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Based on the population data, and as shown in Table 10, all the factors considered, except team size and team location, significantly affect team choice of collaborating with partners from the north. However, if we take a 0.1 confidence level, we reject the null that team location is not associated with collaborating with partners from the north.

On the other hand, the choice of collaborating with partners from the south seems to be associated with the number of PhDs and the extent to which the team leader writes well in a second language only. The z-tests of the effects of individual variables and the Wald Tests of joint effects of the categorical variables confirm these findings.

Table 10: Factors Explaining the Choice of Collaborating with Partners from Northern and Southern Countries

	Int. Res. w/ North	Int. Res. w/ South
Team Size in 2003	0.016	0.026
	(1.14)	(1.88)
Team Age in 2003	0.052**	0.012
	(4.66)	(1.10)
Total PhDs in 2003	0.294**	0.133**
	(7.33)	(3.70)
Leader Writes Oth Langua	0.353**	0.506**
	(2.76)	(3.36)
Leader Studied Overseas	0.508**	0.130
	(4.12)	(0.92)
Tot. Proj. in 2003	0.082**	0.020
	(6.48)	(1.93)
Agrosciences	-0.594*	-0.065
	(2.19)	(0.22)
Medical Sciences	-0.429*	-0.390
	(2.09)	(1.64)
Social Sciences	-0.395*	-0.162
	(2.00)	(0.71)
Humanities	-0.217	-0.081
	(1.29)	(0.42)
Engineering	-0.821**	-0.326
	(3.98)	(1.42)
Other Sciences	0.016	0.113
	(0.05)	(0.35)
Business Sector	0.204	0.224
	(0.54)	(0.55)
Government	0.338	0.020
	(1.10)	(0.06)
Other Sector	1.096**	0.340
	(2.58)	(0.72)
Mid. Home Inst.	-0.467**	-0.225
	(3.39)	(1.42)
Small Home Inst.	-0.453*	-0.303
	(2.11)	(1.19)
Small City	-0.627	-1.364
	(1.10)	(1.33)
Midsize City	-0.255	-0.141
	(1.66)	(0.79)
Constant	-2.181**	-2.422**
	(10.42)	(10.48)
Observations	1889	1889

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Based on the population data, and as shown in Table 11 and discussed before, team size positively affect the choice of hosting foreign researchers. However, it is more important for explaining the choice of hosting researchers from the south than for explaining the choice of hosting researchers from the north. In fact, a one standard deviation increase in team size increases team's odds of hosting researchers from north by a factor of 1.26 (not shown here), but increases team's odds of hosting researchers from south by a factor of 1.30, holding all other variables constant. The difference of the effects of each variable can also be seen by comparing the z-statistics in each model.

The opposite is true regarding the effects of having PhDs in teams. As the number of PhD holders increase, the probability of hosting foreign researchers increases, but it raises more for hosting researchers from the north than for hosting foreign researchers from the south, holding the other variables constant.

Teams led by someone who writes well a second language positively affects the probability of hosting foreign researchers, but it increases it more for hosting researchers from the south than from the north, holding the other variables constant.

Teams led by someone who studied overseas appear more likely to host foreign researchers than teams not led by someone who studied overseas, but this is mostly because this factor affects the choice of hosting researchers from the north and not from the south.

While teams working in the natural sciences are more likely to host foreign researchers than comparable teams working in the agricultural sciences, the social sciences and the engineering. However, this is mostly due to its higher probability of engaging researchers from the north than for its probability of engaging researchers from the south, which is not statistically significant. By contrast, the odds of hosting foreign researchers are higher among the teams working in the natural sciences than among the teams working in the medical science. These differences are statistically significant regarding both types of partners. In this case, the difference in the odds is also higher regarding the choice of hosting researchers from the north than of hosting foreign researchers from the south.

Finally, the higher probability of hosting foreign researchers among teams affiliated with big institutions or located in large cities compared to that of teams affiliated with mid-size institutions or being located in mid-size cities responds mostly to the higher probabilities of the former types of teams to host researchers from the north.

As for the factors affecting the choice of working with foreign funding is concerned, team age appears to affect positively the choice of working with foreign funding, but it affects more the choice of working with funding from the north than of working with funding from the south, holding the other variables constant.

By contrast, although the effects of having PhDs in teams positively affects the choice of working with foreign funding, it seems to affect positively more the choice of funding from the north than from the south, holding the other variables constant.

The extent to which a team has a leader who is able to write well in a second language or studied overseas in the past is more important for explaining the choice of working with foreign funding from the north than for explaining the choice of working with funding from the south (whose effects are not statistically significant).

The number of projects active a team has is important for explaining the choice of both types of funding. However, the effect is greater for explaining the choice of working with funding from the north.

Teams working in the other sciences or in the multidisciplinary sciences are more likely to work with projects funded by southern countries than teams working in the natural sciences. They are also more likely to work with funding from the south than with funding from the north.

Teams affiliated with the government or the NGOs' are more likely to work with foreign funding than comparable teams affiliated with the academy, mostly because the former are more likely to work with funding from the north.

Finally, teams affiliated with large institutions are more likely to work with foreign funding than comparable teams affiliated with small and midsize institutions. However, the main difference is due to their likelihood of working with funding from northern countries.

No significant effects were found regarding the location variables on the probability of working with funding of any origin.

Table 11: Factors Explaining the Choice of Different of Combinations of Types of Partners and Types of Collaboration

	Researchers frm North	Researchers frm South	Funding frm North	Funding frm South
Team Size in 2003	0.040**	0.045**	-0.004	-0.027
	(2.74)	(3.04)	(0.27)	(1.44)
Team Age in 2003	0.015	-0.019	0.050**	0.035*
	(1.28)	(1.27)	(4.53)	(2.54)
Total PhDs in 2003	0.201**	0.113**	0.230**	0.083*
	(5.13)	(2.80)	(6.07)	(2.09)
Leader Writes Oth Langua	0.385*	0.524**	0.481**	0.350
	(2.29)	(2.93)	(3.40)	(1.51)
Leader Studied Overseas	0.371*	0.155	0.478**	0.192
	(2.35)	(0.94)	(3.54)	(0.89)
Tot. Proj. in 2003	-0.011	-0.009	0.084**	0.052**
	(0.97)	(0.69)	(6.81)	(4.00)
Agrosciences	-0.864*	-0.304	-0.294	-0.030
	(2.28)	(0.85)	(1.03)	(0.07)
Medical Sciences	-0.886**	-0.780**	0.023	0.154
	(3.23)	(2.61)	(0.11)	(0.48)
Social Sciences	-0.540*	-0.400	-0.183	0.096
	(2.10)	(1.50)	(0.85)	(0.28)
Humanities	0.088	-0.104	-0.359	-0.504
	(0.46)	(0.49)	(1.92)	(1.52)
Engineering	-1.261**	-0.363	-0.291	-0.299
	(4.15)	(1.39)	(1.37)	(0.83)
Other Sciences	-0.085	-0.634	0.279	0.907*
	(0.24)	(1.41)	(0.88)	(2.30)
Business Sector	0.275	0.303	0.160	0.554
	(0.61)	(0.64)	(0.38)	(0.90)
Government	-0.106	-0.380	0.672*	0.882
	(0.25)	(0.79)	(2.10)	(1.79)
Other Sector	0.244	-0.217	1.812**	1.385*
	(0.50)	(0.35)	(4.06)	(2.15)
Mid. Home Inst.	-0.454*	-0.088	-0.499**	-0.551*

	(2.50)	(0.48)	(3.31)	(2.15)
Small Home Inst.	-0.086	-0.134	-0.734**	-0.933*
	(0.32)	(0.46)	(2.89)	(2.08)
Small City	-1.232		0.019	-0.063
	(1.20)		(0.03)	(0.06)
Midsize City	-0.518*	-0.197	-0.084	0.035
	(2.34)	(0.95)	(0.50)	(0.13)
Constant	-2.499**	-2.545**	-2.667**	-3.415**
	(9.89)	(9.46)	(11.75)	(10.08)
Observations	1889	1856	1889	1889

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

D. Conclusion and Policy Implications

Research team productive capacity and team ability to contribute to local knowledge depend in part on team internal characteristics including its size, its age, the level of education of its members, and their R&D activities. Team performance also depend on the field it specializes in, the sector where it performs its activities, the characteristics of its home institution and the characteristics of its location, among other factors.

The research presented here attempts to provide insights on the policy discussion on the effects of the internationalization process on local S&T capabilities in developing countries. We have seen that research collaboration in general and international research collaboration in particular have great potential for positively affecting local scientific and technological capabilities. Considering the increasing gap between, on the one hand, countries with access to global knowledge and technologies holding leading positions in the race for markets, and, on the other hand, countries that lack the means to meet their local needs, compete, and protect the environment, international research collaboration appears as an effective way to narrow the development distances between the two worlds and, more importantly, provide developing countries better ways to facing their day-to-day challenges. In fact, contrary to development based on aid, monitoring, import, or copy as means to increase local capabilities, international research collaboration can help in building local and longstanding S&T strengths in developing countries while assuring their autonomy, reciprocity and mutual gains for those involved in cooperative activities.

There are some risks associated with international research collaboration, however. Although these negative effects can be hard to avoid, policy tools should be developed to identify their causes, minimize their impact, and prevent from happening if possible.

We found here that international research collaboration significantly affects the Colombian S&T system in a positive way, but we also noticed that its effects depend on the type of collaboration chosen and the type of partner involved. In this sense, we found that although working with foreign funded projects and co-authoring with partners located overseas positively affect team S&T capabilities, hosting foreign researchers does not seem to significantly affect team performance. In this sense, while the linear model argument is supported by the data, the dependency and the outsourcing arguments are rejected.

We also found that although collaborating with partners from the south yields greater impact on team productive capacity than collaborating with the north, it is collaborating with

northern countries that contribute the most to team's ability to add to local knowledge. These finding reject both research hypotheses regarding the diversity and the similarity arguments respectively, however.

Interestingly, working with projects funded by institutions from the south appears to have the greatest positive impact on team's productive capacity. On average, it contributes between 11 and 14 bibliographic products alone. In contrast, working with projects funded by institutions from the north appears to have the greatest positive impact on team's ability to contribute to local knowledge. On average, it raises team's probability of involving Colombia in the research process by between 16% and 18%.

To understand the reasons why a specific combination of collaboration activity and partner would be preferred over another requires further investigation, however. The patterns found here are illustrative of the challenges policy makers would face if they were interested on implementing tools strategically oriented at getting the most benefits possible from their support to team performance and their process of internationalization. The findings reported here are the first steps in that direction. In addition, a more illustrated decision-making process would help teams in gaining from collaborating internationally, and by that means, positively affecting the society as a whole.

In Colombia very few research teams actually collaborate internationally, however. The understanding of what explains international collaboration is an important input for the design of policies in S&T. In this sense, we found that team size, team age, the level of education of its members, the characteristics of the team leader, and the dynamism of the teams help to explain collaborative behavior. We also found that there are differences in the probability of collaborating internationally responding to scientific disciplines, were the teams working in the natural sciences tent to be more cosmopolitan than teams working in the medical sciences, the social sciences and the engineering, but equally cosmopolitan than teams working in the agricultural sciences, the humanities and the multidisciplinary sciences. We also found that teams working in large institutions or located in large cities tend to be more collaborative than comparable teams. Finally, we found that there is no difference associated with the sector the team works in.

However, we also saw that these differences vary depending on the type of collaborative activity and partner. Thus, whereas team size, team education, the characteristics of the team leader, and team location help to explain the choice of hosting foreign researchers; team age, team education, team leader characteristics, team dynamism, scientific field, sector, and characteristics of the home institution help to explain the choice of leveraging foreign funding.

The choice of collaborating with partners from the north seem to be affected by the experience of the team, the education of its members, the characteristics of the team leader, the discipline, the sector, and the characteristics of the home institution. In contrast, the factor explaining the choice of collaborating with partners from the south depends only on the level of education of the research team and the characteristics of the team leader.

Probably the main reason why teams do not collaborate is because they lack public support. In fact, there is plenty of room for government intervention and, as we showed, it is largely justified. Public policies could include tools to encourage physical interaction among scientists, network creation, network membership and operation, access to external information, and diplomatic support among other alternatives. Several ways governments can foster international research collaboration include:

1. Promoting the participation of local teams in international projects,
2. Supporting workshop participation by local scientists, when they are held overseas,

3. Supporting international scientific workshops organized by local research institutions,
4. Funding international dissemination of information related to local scientific activities and communities (through the web, the internationalization of local scientific journals, or the countries' diplomatic representations overseas),
5. Funding local dissemination of information related to international scientific activities (including translation of relevant work into local language) and communities,
6. Sponsoring courses of foreign languages for local researchers,
7. Supporting the negotiation of collaborative agreements between institutions
8. Sponsoring international education at the graduate level
9. Supporting international research internships
10. Sponsoring local access to international databases (both Journal and Patent databases),
11. Supporting programs oriented at attracting foreign researchers and national researchers living overseas to work in or with local institutions,

For this goal, public funding for these activities should dramatically increase. There is no information on government expenditure on the internationalization of local S&T available, but it is easy to guess that the budget assigned to facilitate international research collaboration is meager.

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