North-South and South-South Research Collaboration: What Differences Does It Make For Developing Countries? – The Case of Colombia

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Abstract— **Research collaboration (RC) is associated with both positive and negative effects on the performance of research. It is said to increase creativity, scientific productivity, research quality, innovative capacity, the creation of science and technology human capital, the consolidation of research agendas, the expansion of research areas and disciplines and, ultimately, the development of new or better processes, products and services. Risks and costs associated include the privatization and 'capture' of traditional 'public' knowledge, the 'mercantilization' of knowledge and human capital, and the lost of research autonomy. Little is known about the ways RC affects local scientific and technological capabilities when it involves scientists and engineers working in developing countries, however. This is presumably the result of the popular assumption that there are no specific and distinctive effects associated with the geographical localization of the partners. This research assesses empirically such assumption and explores the effects of collaboration with different types of partners on the performance of research teams working in Colombia, an S&T-developing country. In particular, it explores the performance of 1889 research teams and the effects attributable to partners from northern and southern countries involved into two different types of collaboration activities: hosting foreign researchers, and working with foreign funding. Results from multivariate regressions and non-parametric analyses show that teams collaborating with partners from the south report higher scientific production, while those collaborating with northern countries seem to contribute the most to local knowledge. 20 interviews were performed to assess the plausibility of the models and of the findings. Theoretical and policy implications of the results are discussed.**

***Index Terms*—research collaboration, developing countries, Colombia**

I. Introduction

THE literature is extant in illustrating the sheer boost of international research collaboration (IRC), and many hypotheses have been proposed to explain it. It has been claimed that IRC results from the increased complexity of problems, and the raising costs of research [1, 2], the implementation of government policies explicitly designed to favor the internationalization of science and technology [3, 4], the increased mobility of scientists across borders, and the advancement of the communication technologies and networking. However, little is known about its effects on local scientific and technological capabilities, as well as on the orientation of the research performed.

Research collaboration is commonly associated with *creativity* [5, 6], *scientific productivity* [7-9], *research quality* [10, 11], *innovative capacity* [3, 12, 13], *the creation of science and technology human capital* [14, 15], the consolidation of research agendas, the expansion of research areas and disciplines, and ultimately, the development of new or better processes, products and services.

However, despite this optimistic view, research collaboration is also associated with negative impacts on almost the same aspects, that is, on *research productivity* [16, 17]; *output quality* [18, 19]; *innovative capacity* [20]; *human capital* [21, 22]; and *relevance of the research* [19, 23, 24]. Some of the risks and costs associated include the privatization and capture of traditional 'public' knowledge, the 'mercantilization' of knowledge and human capital, and the lost of research autonomy.

In contrast to the literature on the effects of research collaboration, that on the theoretical or empirical effects of *international* research collaboration is relatively scarce, and, with the exception of few recent works, it is remarkably small regarding the effects of IRC on *developing countries*[1]. In fact, without much empirical support, it is commonly argued that when this research involves the participation of scientists and engineers from developing countries, it increases their S&T

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[1] An extant literature review on the topic can be found in Ordonez [25].

productivity as it "opens the doors" to new knowledge and resources these countries typically do not have [4]. Conversely, it is also frequently claimed that IRC may act as a 'distractor' of local capabilities and work as a type of 'brain-drain-without-mobility', reducing the critical mass needed to face local issues.

Recently, Ordonez studied the performance of 1889 research teams between 2003 and 2005 working in Colombia in all areas and found that IRC is the explanatory variable with the greatest impact on team productivity, right after the number of PhD members a team has, and once all demographic, location, field, and organizational factors are held constant [25]. According to the author, the expected rate of bibliographic production of collaborating teams are nearly 30% as high as that of non-collaborating teams of similar characteristics and, holding all other variables constant at their means, collaborating internationally results in an increase of expected productivity count by nearly 3 bibliographic products.

More interestingly, Ordonez found that collaborating teams are more likely to contribute to local knowledge than non-collaborating teams. Using the extent to which a research team includes the word 'Colombi*' in its projects' and products' titles or abstracts to account for its contribution to local knowledge, the author found that, while 47% of the teams collaborating internationally uses 'Colombi*' in their projects or bibliographic products, only 29% of the teams that do not collaborate internationally uses the country as the unit of analysis or object of their research processes. The author found that, based on the 1889 teams studied, holding all other variables constant, the odds of a team working in research involving 'Colombia' are 1.3 times larger for those collaborating internationally than for those that do not collaborate; and that holding all other variables constant at their means, collaborating internationally increases team's odds of contributing to local knowledge by between 6% and 8% [25].

More recently, Ordonez, Cozzens et al. studied a random sample of 672 Colombian research teams authoring 5491 journal articles published between 1998 and 2005 indexed by the Web of Science to investigate the impact of international research collaboration as measured by the co-authorship of articles produced with partners located overseas, and found that a team's odds of involving Colombia in its research process are 2.2 times larger for those collaborating internationally than for those not doing so [26].

Moreover, a study on the performance of the top 10 Colombian research institutions Ordonez 2005 found that those co-authoring with partners located in foreign countries tend to publish their work in journals of higher impact factor[2] and receive more citations per article than those not co-authoring with partners located overseas [27].

This paper draws from previous work and attempts to contribute to current understanding of the issue at hand by addressing the basic question *To what extent does different types of partners explain differences in the performance of research in developing countries?* More specifically, *does collaborating with partners from the global north yield different results than collaborating with partners from global south? In what sense?*

It is commonly argued that the dichotomy North-South is pointless as both S&T communities are composed by similar actors, respond to similar motivations, seek to answer to similar questions, and work with similar tools. This, in fact, is a hypothesis worth testing. Most of the scientists interviewed in Colombia in the framework of this research responded that they do see many differences. To test this hypothesis empirically, we use Colombian data and look at the performance of its local research teams both in terms of productive capacity and the orientation of the research performed. Before turning to the discussion of the models and the methods used, let us briefly familiarize the reader with the Colombian S&T context.

II. Colombian S&T Context

Colombia constitutes a good case to study the effects of IRC on developing countries for at least three reasons. First, as in many developing countries, it experiences a rapid process of institutionalization of the scientific and technological community as part of its efforts to benefit from the so-called knowledge economy. According to the Colombian Observatory of Science and Technology, the number of researchers affiliated to centers rose from less than 5,000 in 1995, to more than 12,000 in 2000, to nearly 20,000 in 2005. By 2009, these centers hosted most of the Colombian scientific community estimated to be of more than 24,000, of which more than 12,000 report periodic research outputs. Nowadays, more than 80% of the researchers reporting S&T products are affiliated to a research team [28].

Second, as in many developing countries, S&T internationalization is taking place at a rapid pace. The proportion of articles published in collaboration with foreign partners grows steadily and, as shown in table 1, since the 90s the number of such articles published in high quality journals outnumbers those written without international collaboration. In fact, the number of countries with which Colombian scientist collaborates is continuously increasing, both from the northern and lately from the southern countries. This is consistent with finding by [29, 30]

Similarly, the number of international scientists affiliated with Colombian research teams and the number of foreign funding organizations sponsoring local research have also increased consistently over the last decade.

Third, as most S&T-developing countries, Colombia lacks appropriate amounts of scientist and engineers, infrastructure, investment, and institutional support. This can be seen by looking at the self explanatory table 2 shown below; where Colombia appears to be an "average country" in Latin America based on key input and output indicators.

[2] The impact factor of the journals indexed by the Web of Science database takes into account the number of cites received in a given year weighted by the number of articles published in the last two years of the given journal. The higher this ratio is, the better the journal is assumed to be.

TABLE I

CO-AUTHORSHIP OF ARTICLES IN ALL FIELDS EXCEPT IN SOCIAL SCIENCES AND THE HUMANITIES

Year	Articles	% IRC-articles	Partner Countries	Core Partners (3 or more joint articles)	Core Northern Partners	Core Southern Partners
1980	50	28%	12	1	1	0
1985	62	32%	13	3	2	1
1990	111	46%	26	13	7	6
1995	185	52%	52	24	12	12
2000	637	64%	64	35	21	14
2005	884	68%	65	41	22	19
2010	1826	60%	112	81	35	46

Source: ISI: SCI-Expanded.

TABLE II

LATIN AMERICA: SELECTED INPUT AND OUTPUT INDICATORS. 2008

Country	Population in Millions	Expenditure on S&T as % of GDP (a)	Researchers (head count) per thousand labor force (b)	% of researchers with PhD (c)	Invention coefficient (d)	Publications in SCI as % or World	Publications in SCI per 100 researchers (head count) (e)
Argentina	39,7	0,6%	3,95	24,5%	2,0	0,6%	11,9
Brazil	189,6	1,4%	2,10	32,9%	3,8	2,3%	15,1
Chile	16,8	0,7%	2,78	NA	3,2	0,3%	16,3
Colombia	44,5	0,4%	0,76	21,3%	0,3	0,2%	14,6
Costa Rica	4,4	1,4%	1,71	16,3%	0,5	NA	12,6
Ecuador	13,9	0,4%	0,44	6,6%	0,1	NA	13,1
México	106,7	0,4%	0,88	NA	0,6	0,7%	22,4
Perú	28,7	0,1%	0,39	7,1%	0,1	NA	6,7
Uruguay	3,3	0,8%	1,35	50,6%	1,0	NA	31,4
Venezuela	27,9	2,5%	0,48	53,7%	0,4	0,1%	25,4

(a) Chile, Peru: R&D as % of GDP 2004

(b) Chile, Peru: 2004; Mexico: Full Time Equivalent: 2007

(c) Peru: 2002

(d) Ecuador: 2005; Peru: 2007

(e) Chile, Peru: 2004; Mexico: Full Time Equivalent: 2007

Source: RICyT

Let us turn now to the discussion of the theoretical model and the statement of the research hypotheses guiding the research.

III. THEORETICAL MODEL AND RESEARCH HYPOTHESES

As suggested earlier, this research seeks to contribute to the understanding of the effects of international research collaboration (IRC) on the performance of research in developing countries, and uses Colombian research teams as unit of analyses. In particular, we are interested on the characteristics of the research partners to assess whether they affect differently both bibliographic production and research orientation. We rely on the literature found on the topic by sociologists of science and technology, innovation scholars, economists, and political scientists to draw the hypothesis proposed to guide the research performed.

As discussed earlier, IRC may open access to knowledge, provide resources allowing the teams to engage students, and help shape and strengthen the team's research agenda and orientation. However, it may also entail negative effects on team performance, decreasing productivity and detouring research team orientation. In the Colombian case Ordonez proved that the effects are rather positive. The question addressed here is therefore, to what extend do different type of partners affect the ways IRC contribute to team productivity and team contribution to local knowledge in Colombia?

A. IRC and Team Productivity in Developing Countries

Governments and institutions encourage or require the collaborative production of knowledge when scientists apply for funding because of the assumed positive effects this has on creativity. The mechanism through which collaboration increases creativity is little understood, however. While the literature on the virtues of external peer review on research quality is rather well developed [31], that related to the phenomena occurring within the collaborative process between partners is relatively new.

The issue is the object of study by sociologists, psychologists, economists, organizational theorists, and recently by policy scholars. Social capital and lately social network theorists have taken the lead in providing insights on the role played by research collaboration on creativity [6, 11, 32-43].

According to Granovetter [38], individuals with a large number of "weak ties," that is, relationships with people from outside of their closest circle, are more likely to access information from distant parts of the social system and less likely to be confined to the provincial news and views of their close friends, placing them into an advantageous position in the market [38, 44].

Allen [43] claims that individuals with more contacts outside the organization ("gatekeepers") are advantageously situated for facilitating information flow and serve as the primary link to external sources of information and technology: a critical role for importing novel information and linking the organization with its environment [43]. Burt (2004), inspired by Mills (1848), claims that people connected with a greater diversity of groups are more familiar with alternative ways of thinking, which gives them more options to select from and synthesize, increasing their probability of having good ideas [6, 45].

Relying on the literature on research collaboration we propose the following arguments to better understand the impacts of *international* research collaboration on team productivity in developing countries. On the one hand, positive effects of international research collaboration on research productivity can be based on four arguments: a) the "more-is-better" argument, b) the "complementarity-based-on-diversity" argument, c) the "complementarity-based-on-similarity" argument, and d) the "linear-model" argument.

The "more-is-better" argument is the simplest and more commonly found in the literature. This argument clams that as

foreign partners are involved in the research process, more bibliographic outputs can be produced. In Beaver's words, citing one of his interviewees, "[one] can put one student into the field for the summer, 3 months (…) after 5 years, [one will] have enough data to produce a research publication. A large research group can put 5 students in the field for the summer, 3 months. But in 3 months, the research group already has the data for a publication" [9]. As the author adds, "like the advantages (…) of parallel processing, one can parcel out parts of a problem, and finish more rapidly than one's competition."

The second argument, the "complementarity-based-on-material-diversity" argument, is found on the literature in sociology of science and differs to the previous argument in that it includes a qualitative criterion associated with the characteristics of the partner. In this framework, the greater the differences between the partners, the better, as in a collaborative enterprise everyone would offer something the other lacks and would get something would not be possible or easier to get otherwise. According to this argument, by collaborating with partners of different characteristics one can get a better understanding of one's own problems by studying one's partners' problems and/or working on their solutions. By doing so, we complement our knowledge with that of our peers. This is largely the "strength-of-weak-ties" argument proposed by Granovetter and Burt who claim that one has more to learn from those that see or have things one does not see or have, than from those of similar characteristics [6, 33, 38].

Levine and Moreland (2004) also support this argument. According to the authors, for whom human cognition is an interpersonal as well as an intrapersonal process, research collaboration increases creativity particularly when it involves some degree of diversity, which may stimulate divergent thinking [5]. Beaver (2001) claims that "multiplicity of viewpoints energizes and excites participants, makes actual work more intense and stimulates creativity." Research collaboration among members of different epistemic communities is one of the most important causes of the rapid progress in S&T in most developed countries, where "complex problems are better faced by teams appealing to multiple approaches in a process where each of the participants learns something new and sometimes unexpected from their colleagues" [9]. As Fleming (2001) argues, the main function of R&D is indeed to generate new knowledge by recombining existing knowledge, and "when expertise is shared, it makes the sum stronger than the parts" [46].

The "complementarity-based-on-epistemological-similarity" argument is also based on the literature in sociology of science and also takes into account the characteristics of the partners. Based on this argument, a collaborative research is more productive when it involves partners that are compatible in many senses. This argument claims that for practical reasons, and to be successful in the research enterprise, one needs to work with partners with whom one shares similar paradigms, methods, views and values. It also draws from the literature that claims that personal empathy in terms of gender, age, social status, origin, language, ideology, experience, professional practice, professional ethos, religion, etc., is decisive.

As Levine and Moreland (2004) claim, similarity among partners may facilitate communication and interaction and by that means creativity: "[c]reativity in science, as in most other domains, involves more than simply generating a set of novel ideas (divergent thinking). It also involves narrowing this set to one alternative (convergent thinking) and then implementing this alternative by empirically testing and communicating it to the scientific community" [5]. To Farrell, shared cognition, which constitutes the basis for research collaboration, implies a "shared set of assumptions about their discipline, including what constitutes good work, how to work, what subjects are worth working on, and how to think about them" [37].

Finally, the "linear-model" argument also claims positive effects of international research collaboration as it sees the collaborative process as an input-output process, where every collaborative input (foreign researcher or foreign funding) results in an S&T product. It differs from the "more-is-better" argument as it sees a more deterministic relationship between efforts and results.

On the other hand, negative effects of research collaboration is much less prolific but similarly inspiring to base upon to draw hypotheses on the effects of international research collaboration on developing countries. In fact, in the research collaboration literature, negative effects of have been attributed to the costs associated with the management of the collaborative enterprise. This is referred to as the "transaction-costs" argument. This argument contradicts the "more-is-better" argument as it claims that each additional researcher or funding source involved in the collaborative enterprise comes with a cost associated with it, which may affect research productivity. Katz and Martin (1997) claim that research collaboration increases costs on travel, administration, and time spent on keeping all collaborators informed of the progress, deciding what to do next, developing new working relationships, resolving different opinions, and reconciling differences in management cultures, financial systems, rules on intellectual property rights, rewards systems, and promotion criteria [47]. We hypothesize that these costs are higher when involving developing countries in the collaborative enterprise. We cannot test these hypotheses yet, however.

Other arguments associated with the negative effects of the collaborative activity include the fact that sometimes partners collaborate without the intention to make public their findings (i.e the "inconvenience argument"), or that the lack of match between partners makes collaboration difficult and therefore unproductive. To the author's knowledge, current literature does not offer empirical support to most of these arguments, however.

The use of a developing country as a case study to better understand the effects of international research collaboration on S&T capabilities seems to be better for this purpose than studying the effects of collaboration between developed countries. We assume this is true, mostly because the differences between a developed and a developing country partners tend to be larger, which makes the assessment of impact or gains easier from the methodological point of view. This allows testing the assumption that asymmetries lead to important gains for those in the seemingly disadvantaged position. This is the basis of the "diversity argument" discussed earlier.

Similarly, the study of the research collaboration pattern and effects in the context of a developing country can also contribute to the testing of the "similarity argument" as South-South collaboration mostly happens among neighbor countries sharing similar resources, views and problems (not to mention history, language, religion and culture characterizing, for instance, most Latin-American countries).

Besides the effects attributed to research collaboration as discussed earlier, international research collaboration can affect developing countries in a variety of ways. It can give local scientists and engineers access to new knowledge and research resources they would not have otherwise within their national boundaries [4]. 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. These benefits can hardly be obtained in isolation from the global science and technology system. However, international research collaboration can also increase their loss of autonomy and 'distract' local capabilities and critical mass needed to face local concerns, forcing them to address 'irrelevant' issues [24]. This is the topic discussed in the next section.

B. IRC and Research Orientation in Developing Countries

The literature on the impact of international research collaboration on the orientation of the research performed is astonishingly silent. The reasons why there are few studies on the issue may be that, on the one hand, it is usually hard to define and account for the concept of "orientation" or "relevance" implicit in this variable. In fact, given the intrinsic characteristics of the scientific activity and its outcomes (it is a public good, it does not extinguish once it is used, etc.) it is hard to judge whether a specific contribution to knowledge is relevant or not. Questions such as "for whom?", or "when?" are often well grounded as there is no way to know whether what today is "irrelevant" is not going to be "crucial" for tomorrow's scientific development [48].

Nevertheless, from the public policy perspective, the issue of "relevance" or "pertinence" is a matter of concern that has been around for a long time (e.g. Knowledge for what? [49, 50]). Indeed, as any other human activity that typically demands large support from governments, the performance of science and technology activities are perceived to have the moral obligation to make effective contributions to the betterment of the societies that sponsor their activities [51-53].

Regarding international research collaboration, the hope from the policy perspective is that local teams take advantage of the cognitive and material resources provided by their foreign partners to increase their contribution to the stock of local knowledge, hence increasing local S&T capacity to solve local problems.

We argue this is particularly true in the case of developing countries, where local endowments of S&T capabilities are relatively scarce. This concern is consistent with the literature that sees knowledge as an opportunity for development, and "development as freedom" [54, 55]. In this framework, the hope is therefore that by doing R&D activities in these developing countries, working on their own problems or using their countries as laboratories thanks to a collaborative activity with foreign partners will benefit their society and economy in the long run. The opposite may entail large opportunity costs.

In fact, if working on R&D activities in the framework of a collaborative activity is considered good for the developing country, working in their own country or using their country as the focus of their collaborative research should be considered as even better.

Hence, four arguments are proposed to explain the effects of international research collaboration on research orientation. Arguments claiming positive effects include the "complementarity-based-on-epistemological-similarity" argument discussed earlier and the "commitment" argument. In contrast, arguments claiming negative effects of international research collaboration on research orientation include the "opportunity" argument and the "outsourcing" argument.

Positive effects of international research collaboration on research orientation to local issues may be based on the fact that we can get a better understanding of our problems by working on issues that are common to partners of similar characteristics in all relevant aspects (i.e. the "complementarity-based-on-epistemological-similarity" argument). Similarly, international research collaboration can also have a positive effect on research orientation in the sense that sometimes there might be bounds of some sort (contractual, personal, etc.) that leads to a commitment to work on local issues in developing countries (i.e. the "commitment" argument).

In contrast, negative effects of collaborating with international partners on research orientation may be based on the existence of a relationship characterized by subordination. Foreigners may be interested in working with researchers and engineers from developing countries because of their calculations of the quality/price ratio (i.e. the "outsourcing" argument). In addition, researchers may be required to work on foreign issues because they do not have any other choice, or because they perceive in the collaborative activity an opportunity to work on issues of their own interest or expertise, which may not in turn be related to local issues (i.e. the "opportunity" argument).

Another reason why there are so few studies on the issue may not only be because it is risky to draw conclusions from, but also because it is materially hard to operationalize. However, the fact that it is hard to measure, and potentially misleading, should not be considered as a reason for not attempting to study it, as there is a real demand of information on that issue. Caution in its interpretation is needed, however. Fortunately, new and better information and software tools are increasingly making this task easier, allowing policy researchers to make useful contributions to the on-going and never-ending discussions on the topic in the S&T Policy arena.

C. Statement of the Research Hypotheses

To sum up the discussion presented here regarding the ways international research collaboration potentially affects research performance in developing countries, one can hypothesize that while collaborating with partners from the North positively affects team productivity because of its contribution in terms of material complementarity (i.e. the "diversity argument"), collaborating with partners from the South positively affects

team orientation because of its contribution in terms of cognitive complementarity (i.e. the "similarity argument").

Taking this debate to the international relations literature, and from the perspective of a developing country, it could be the case that, if the "similarity argument" discussed earlier is right, international collaboration with partners from 'similar' countries (i.e. South-South collaborations) would have better effects than collaboration with partners with different characteristics (i.e. North-South collaborations). Such a finding would lead to a policy emphasizing South-South collaborations in developing countries.

Hence, the analysis of the effects of international research collaboration on team productive capacity depending on the characteristics of the partner is based on the testing of the following research hypotheses:

H1. Teams that collaborate with partners from the North have more bibliographic products than teams that do not. This hypothesis is based on the "complementarity-based on material-diversity" argument.

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

H2. Teams that collaborate with partners from the South are more likely to use 'Colombia' in their research projects and products than teams that do not. This hypothesis is based on the "complementarity-based-on-epistemological-similarity" argument found in the Science, Technology and Society (STS) literature.

IV. Methodology

In this study, 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 two ways: 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.

The distribution of partner countries based on their level of S&T development can be found in the appendix of this paper.

To account for the effects of international research collaboration depending on the characteristics of the partner on research team productive capacity and to test the research hypotheses stated we use zero-inflated negative binomial regression models (ZINB) to predict counts in a highly skewed distribution. These models were implemented following Long and Freese [56].

The models are:

$$Zinb\ totbibprod05 = a + \beta 1IRCN05 + \beta 2IRCS05 + \beta 3Core03 + \beta 4age03 + \beta 5totphds03 + \beta 6totprojects03 + \beta 7agroscs + \beta 8medscs + \beta 9social + \beta 10human + \beta 11engi + \beta 12othscs + \beta 13bussector + \beta 14govsector + \beta 15othsector + \beta 16medinst + \beta 17smallinst + \beta 18smallcity + \beta 19medcity$$

where team productive capacity is measured by the total number of bibliographic products done between 2003 and 2005, "totbibprod05," and the independent variables, international research collaboration with partners from northern and southern countries, are represented by dummy variables, "IRCN05" and "IRCS05" respectively coded 1 if the team had foreign researchers and/or foreign funding between 2003 and 2005 from northern (or southern) countries, 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.

To account for the effects of international research collaboration on research team's ability to contribute to local knowledge depending on the characteristics of the partner and to test the research hypotheses stated we use logistic regressions following Lewis 2003 [57].

The following models are used:

$$Logit\ \text{ppkeycol05} = a + \beta 1IRCN05 + \beta 2IRCS05 + \beta 3to\beta 6team\ characteristics03 + \beta 7to\beta 10\text{Field} + \beta 10to\beta 13Sector + \beta 14and\beta 15institusize + \beta 16and\beta 17location$$

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 Propensity Score Matching approach is used to control for selection bias using counterfactuals. This approach was implemented following Caliendo and Kopeining 2008 [58].

The analyses are done on cross sectional data of 1889 Colombian research teams active between 2003 and 2005 working in all scientific fields. A database was built from two data sources publicly available: CvLAC, GrupLAc[3]. Table 3 presents the sampling strategy, and table 4 presents descriptive statistics of the variables used in the models. Standard robustness check techniques were applied to correct for heteroskedasticity in the case of the multiple regression analyses, and to assess the quality of the matching algorithm used in the nonparametric analyses[4].

TABLE III

SAMPLING STRATEGY BASED ON TEAM CHARACTERISTICS

Total Teams Registered in 2005 by Colciencias	3342
Teams Excluded (of which:)	1453
Teams created in 2005 (i)	6
Teams with less than 2 R/E active* by 2003 (ii)	919
Teams with no R&D projects active** btw 2003 and 2005 (iii)	1172
Teams used in the analysis of the larger sample	1889

Sums do not add up due to double counting of teams' attributes

(i) This is justified as many teams may form only to be registered as such by Colciencias during the registration process

(ii) This is justified as there is no "team" of only one member

(iii) This is justified as there is no "research team" without at least one R&D project acting as their main common activity

* An active R/E is a Researcher or Engineer that reports research activities done in 2003 or before

** An active R&D project refers to Research and Development work reported as being in progress between 2003 and 2005

TABLE IV
DESCRIPTIVE STATISTICS

Variable	Mean	Std. Dev.	Min	Max
totbibprod05	8.860773	13.78552	0	138
ppkeycol05	.3605082	.4802751	0	1
Core03	7.258338	5.71711	2	74
age03	6.904711	5.837255	0	68
totphds03	1.455267	2.210634	0	47
totprojec~03	5.75172	6.603742	0	70
totbibprod03	30.34569	43.87513	0	458
leadewrit~05	.5473796	.4978819	0	1
leadstudo~05	.5542615	.4971786	0	1
natscs	.2329275	.4228084	0	1
agroscs	.0608788	.2391711	0	1
medscs	.126522	.3325247	0	1
social	.1614611	.3680531	0	1
human	.2419269	.4283637	0	1
engi	.1339333	.3406708	0	1
othscs	.0423504	.2014407	0	1
educsector	.9052409	.2929595	0	1
bussector	.0338804	.1809691	0	1
govsector	.0386448	.1927979	0	1
othsector	.0206458	.1422333	0	1
smallinst	.1678137	.3737997	0	1
medinst	.3785071	.4851434	0	1
biginst	.4536792	.4979816	0	1
smallcity	.0174696	.1310476	0	1
medcity	.2191636	.4137893	0	1
bigcity	.753838	.4308881	0	1
IRC05	.3896241	.4877941	0	1
ircN05	.3128639	.4637822	0	1
ircS05	.1604023	.367076	0	1
peopN05	.1344627	.3412391	0	1
peopS05	.1064055	.3084376	0	1
projN05	.2382213	.426108	0	1
projS05	.0629963	.2430206	0	1

N= 1,889 Research Teams

In addition, 20 interviews were done to team members to provide the qualitative information needed to assess the plausibility of the models and results and to interpret the findings and their implications.

V. FINDINGS

International Research Collaboration and Team Productive Capacity

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

The effects of international research collaboration on team productivity depend on the type of partner the team collaborates with. As table 5 shows, 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 3 and 4 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 from southern countries appears contributing more on team productivity than funding from northern countries and that hosting foreign researchers from southern countries. Hosting researchers from northern countries does not seem to be associated with team productive capacity in Colombia, however.

Regarding the effects of international research collaboration on team orientation, and contrary to the findings related with team's productive capacity, collaborating with partners from the South does not appear to be significantly associated with team's contribution to local knowledge. Contrary to our hypotheses, we found that it is working with partners from the north that results on positive effects on team's likelihood to contribute to local knowledge. As table 6 shows, this effect is mostly due to the effect of working with foreign funding from these countries. No association was found

[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.

[4] A detailed description of the implementation of the techniques used can be found in Ordonez 2008.

between team's contribution to local knowledge and whether or not the team hosted a foreign researcher.

TABLE V

IMPACTS OF DIFFERENT TYPE OF COLLABORATION AND PARTNER ON TEAM PRODUCTIVE CAPACITY: ZINB AND PSM

	ZINB			PSM			
	%	Count	P>|z|	0.01	T-stat	0.05	T-stat
Internat. Res. Coll.	29	2.66	0.000	2.08	2.71	2.4	3.18
Int. Res. with North	11	1.57	0.140	0.91	1.02	1.68	1.95
Int. Res. with South	46	3.35	0.000	2.97	2.51	4.00	3.45
				-	-	-	
People from North	-7	-0.24	0.348	0.64	0.65	0.02	-0.02
People from South	32	1.91	0.002	0.39	0.38	1.84	1.87
Funding from North	20	2.12	0.014	3.10	2.82	3.20	3.00
Funding from South	52	4.99	0.000	5.71	2.73	8.7	4.23

Observations: 1889

TABLE VI

INTERNATIONAL RESEARCH COLLABORATION AND TEAM CONTRIBUTION TO LOCAL KNOWLEDGE: LOGIT AND PSM

	Logit			PSM (%)			
	% (1)	%(2)	P>|z|	0.01	T-stat	0.05	T-stat
Internat. Res. Coll.	30.3	6.0	0.029	7.8	2.57	8.0	2.73
Int. Res. with North	51.9	9.6	0.001	11.9	3.57	11.2	3.60
Int. Res. with South	0.8	0.2	0.961	2.1	0.64	4.3	1.31
People from North	14.3	3.1	0.409	2.9	0.80	4.4	1.26
People from South	-17.5	-4.2	0.290	-2.8	-0.76	-0.5	-0.15
Funding from North	50.0	9.4	0.004	12.8	3.58	14.2	4.24
Funding from South	23.7	4.9	0.359	9.9	1.98	17.2	3.58

Observations: 1889

%(1): Percentage Change in Odds

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

VI. CONCLUSIONS AND POLICY IMPLICATIONS

International research collaboration appears to have great potential to narrow the development distances 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. The findings reported here support the claim that international research collaboration is positively associated with both research team productive capacity and team's ability to contribute to local knowledge in Colombia.

Moreover, we found that the type of partner seem to matter for boosting local S&T capabilities in developing countries. We found that collaborating with partners from the south yields the greatest impact on team's productive capacity, and that collaborating with northern countries contribute the most to team's ability to add to local knowledge. These findings do not provide evidence to support the research hypotheses proposed regarding the diversity and the similarity arguments respectively, however. As shown in table 7, we hypothesized that collaborating with northern countries yields positive impacts on team productivity, but this relationship was found statistically no significant. In contrast, we did not have a specific hypothesis on the effects of collaborating with partners from southern countries on team productive capacity, as we did not find plausible explanations to this relationship. To our surprise, this was found positive and statistically significant. Intrigued by such results we turned to our interview data and came across with one scientist claiming that partners from northern countries do not care as much as partners from southern countries about their expenditure on R&D. Although we cannot take this testimonial as representative and generalizable, we find it compelling and worth of further exploration.

We also found that our hypothesis stating that working with partners from southern countries would have positive effects on team's probability to involve Colombia in its research process was also not supported by the data. Furthermore, we found that working with partners from northern countries is positively associated with team's likelihood of working on local issues, a relationship we did not hypothesized upon and for which no reference was made by the interviewed. This finding in fact contradicts the claim discussed earlier that northern countries "outsource" research done in southern countries taking the advantage of the relative favorable quality/cost ratio.

TABLE VII.

SUMMARY OF RESEARCH HYPOTHESES AND OF THE RESULTS OBTAINED

	Hypothesized Effect	Observed Effect	Hypothesis Confirmed?
RTPC			
North	Positive	Not Significant	Maybe
South	-	Positive	-
RTCLK			
North	-	Positive	-
South	Positive	Not Significant	Maybe

Finally, and equally interesting, we did not find association between the team's choice to host foreign researchers and its research performance. This can be interpreted as not supporting the rationale behind the exchange programs designed to increase researchers' mobility or, totally the opposite, the need to facilitate such process as high transaction costs may be keeping those teams from working on S&T issues as they may spend some time and resources trying to "accommodate" such researchers. Definitely a finding worth exploring further.

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