

Exploring the Effects of North–South and South–South Research Collaboration in Emerging Economies, the Colombian Case

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Abstract

International research collaboration (IRC) is associated with both positive and negative effects on the performance of research in emerging economies. While some authors claim that North–South collaborations improve scientific quality and visibility for Southern countries, others claim that it may entail the reorientation of research to comply with Northern agendas. South–South collaborations are thought to increase the focus on local affairs, therefore leading to a relatively small number of scientific international publications appearing in “high quality” journals. Research on the impact of IRC beyond publications in international journals has been neglected despite the importance of other products in knowledge creation. This research uses a broad range of scientific outputs to empirically assess such assumptions and explore the outcomes of IRC in Colombia. Results from multivariate regressions and nonparametric analyses show that, contrary to common assumptions, Colombian research teams collaborating with partners from the global South report higher scientific production, while those collaborating with Northern countries seem to contribute to local knowledge the most.

KEYWORDS: international research collaboration, North–South collaboration, research team performance, Colombian STI system, S&T capabilities, local knowledge, research productivity, research orientation, research impact

国际合作与对新兴经济体研究绩效的正面和负面影响相关。虽然有些作者声称南北合作提高了南方国家的科学质量和知名度，但另一些人则声称这可以导致重新调整研究方向以符合北方的议程。据信，南南合作增加了对地方事务的关注，因此导致出现在“高质量”期刊上的国际科学出版物数量相对较少。尽管其他产品在知识创造中也很重要，但有关国际研究合作对国际期刊出版以外影响的研究已被忽略。这项研究使用了广泛的科学成果，以经验方式评估了这些假设，并探索了哥伦比亚国际研究合作的成果。多元回归和非参数分析的结果表明，与普遍的假设相反，与来自全球南方的合作伙伴合作的哥伦比亚研究小组报告的科学产量更高，而与北部国家合作的研究团队似乎做出了贡献更多关于本地知识。

关键词: 关键词: 国际研究合作, 南北合作, 研究小组的表现, 哥伦比亚科学, 技术和创新系统, 科技能力, 当地知识, 科学生产力, 研究方向, 研究影响

La colaboración internacional está asociada con efectos positivos y negativos en el desempeño de la investigación en economías emergentes. Mientras que algunos autores afirman que las colaboraciones Norte-Sur mejoran la calidad científica y la visibilidad para los países del Sur, otros afirman que puede conducir a la reorientación de la investigación para cumplir con las agendas del Norte. Se cree que las colaboraciones Sur-Sur aumentan el enfoque en los asuntos locales, por lo tanto, conducen a un número relativamente pequeño de publicaciones científicas internacionales que aparecen en revistas de “alta calidad”. Los estudios sobre el

impacto de la colaboración internacional en la investigación más allá de las publicaciones en revistas internacionales se han descuidado a pesar de la importancia de otros productos en la creación de conocimiento. Este estudio utiliza una amplia gama de resultados científicos para evaluar empíricamente tales supuestos y explorar los resultados de la colaboración internacional en investigación en Colombia. Los resultados de las regresiones multivariadas y los análisis no paramétricos muestran que, contrariamente a los supuestos comunes, los equipos de investigación colombianos que colaboran con socios del Sur global reportan una mayor producción científica, mientras que aquellos que colaboran con los países del norte parecen contribuir más al conocimiento local.

PALABRAS CLAVE: Colaboración internacional en investigación, Colaboración Norte-Sur, desempeño de los grupos de investigación, Sistema Colombiano de Ciencia, Tecnología e Innovación, Capacidades de C&T, conocimiento local, productividad científica, orientación de la investigación, impacto de la investigación

Introduction

Research collaboration is a rule in science (Katz, 2000), and as Katz and Martin (1997) recognized, it is a phenomenon that goes beyond co-authorship in publications. Its definition ranges, indeed, from joint project formulation, informal discussions, information sharing, and knowledge recombination (Chavarro & Orozco, 2011; Orozco, Ruiz, Bonilla, & Chavarro, 2013). We argue that research collaboration is communitarian work to achieve new knowledge that cannot be divided into pieces of individual contributions in the light of intellectual property rights only (Orozco, 2015; Orozco & Chavarro, 2010).

Due to research collaboration, scientific productivity, understood as efficient use of resources leading to high quality products, improves with variations across scientific fields (Abramo, D'Angelo, & Di Costa, 2009; Ruiz et al., 2010) and different patterns of internationalization as shown in cases from Europe (Abramo, D'Angelo, & Solazzi, 2011) and Latin America (Orozco & Villaveces, 2015). Besides the obvious condition of partners being from different nations, international research collaboration (IRC) produces impacts that are different to research collaboration between researchers from the same country. This is one of our main hypotheses and we strive for testing it in this paper. As we will explain later, the modalities of IRC investigated here include (1) working with foreign partners affiliated with local teams and (2) working on projects with foreign funding.

The literature is extant in illustrating the sheer increase in IRC as a common research practice. Several studies with broad-ranging data demonstrate that IRC improves scientific production (as measured by the number of publications in high quality journals and of citations) as compared with domestic collaboration and even with individual research (Bordons, Gomez, Fernández, Zulueta, & Mendez, 1996; Dutt & Nikam, 2014; Glänzel, 2001; Glänzel & Schubert, 2004; Ordóñez, 2008; Puuska, Muhonen, & Leino, 2014; Tang & Shapira, 2011). However, the literature on IRC involving Southern countries and their theoretical and empirical effects in terms of scientific productivity and research orientation is remarkably scarce (Melkers & Kiopa, 2010).

IRC between North and South¹ countries is of course not new and could be traced back at least to the times of Humboldt (De Greiff & Nieto, 2005). Historical, geopolitical, and linguistic factors determine the distribution of collaborative research between

North–South (Velho, 2002; Vessuri, Guédon, & Cetto, 2014). North–South research collaboration is seen as an important tool to create capacities in emerging economies by creating knowledge and technologies that could be used to alleviate social problems like poverty and neglected diseases (Baud, 2002; Binka, 2005; Morel et al., 2005; Orozco, Buitrago, & Chavarro, 2012; Orozco & Chavarro, 2011; Simon, McGregor, Nsiah-Gyabaah, & Thompson, 2003). Also, the literature shows that Southern countries that engaged in collaboration with the North, increased their international scientific production (Gaillard, 1994) and ensured that their results became part of the global public goods in the institution of science (Baud, 2002). In the case of India, Bhattacharya, Kaul, Shilpa, and Sharma (2015) reported that “international collaboration was again found to be an important contributor of India’s publication growth and attracting visibility.” This could be explained by the increase of international co-authorship in India, from 18.8% in 2001–2005 to 19.5% in 2006–2010.

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 (Velho, 2002; Vessuri et al., 2014). In fact, it has been claimed that IRC between North and South countries is asymmetrical, where the North partners exert dominance in defining research agendas and steer funding, and the South provides a relatively cheap workforce (Gaillard, 1994; Kreimer & Levin, 2013; Vessuri et al., 2014).

Moreover, in addition to North–South IRC, and as Binka (2005) claims “forming effective South–South research collaborations is equally important” (p. 208) to create capacities to address local problems. In fact, South–South IRC has been increasing by regional agreements signed by countries, as is shown in the case of Latin America (Russell, Ainsworth, del Río, Narváez-Berthelemot, & Cortés, 2007) and the Southern African Development Community (Boshoff, 2010). South–South IRC represents other benefits such as the reduction of research costs and, most importantly, the possibility of directing the scientific work on common problems toward local issues (Binka, 2005; Boshoff, 2010).

In the case of Latin American countries, agreements like Mercosur and programs like the Ibero-American Cooperation for Scientific and Technological Development Programme (CYTED in Spanish) influence the intra-regional IRC (Chinchilla-Rodríguez, Benavent-Pérez, Moya-Anegón, & Miguel, 2012; Russell et al., 2007). The cooperation promoted via funding by the European Union Framework Programmes is discussed in the literature of research collaboration in Latin America, which, according to some authors, despite the increase in scientific publications the impact of research on local development is scarce (Bonfiglioli & Marí, 2000; Kreimer & Levin, 2013).

This paper attempts to contribute to current understanding of the issue at hand by addressing this basic question: *To what extent does North–South and South–South collaboration explain differences in the performance of research teams in emerging economies in terms of productivity and local orientation of research?* To answer to this overarching question, we study the case of Colombia.

For so doing, this article is structured in six sections, including this introduction. In the following section, we present the main scene characterizing Colombia’s research terms performance and their international activity in terms of both hosting foreign researchers affiliated to local research teams (from now on, foreign researchers

or foreign partners) and working with foreign funding (Institutionalization and Internationalization of Colombian Scientific Research). We will argue that Colombia is a good case to study to answer the overarching research question. At the end of the section, we will fine-tune the research question this paper is meant to address.

Second, we will offer the relevant theoretical debates on the impact of IRC between researchers and institutions from Northern and Southern countries as a background to better understanding the research done. This is done in the light of organizational theory and sociology of science literature. In this process, we will draw some key research hypotheses.

Third, we describe the methodology, based mostly on quantitative methods; then, we report the results of the exercises; and finally, we discuss their implications from both the theoretical and the policy points of view. We claim that studies like this one are highly necessary, in order to better understand innovation theory, policy, and practice in the framework of contemporary global systems, particularly when they concern emerging economies (Kuhlmann & Ordóñez-Matamoros, 2017).

Institutionalization and Internationalization of Colombian Scientific Research

Colombia constitutes a good case to study the effects of IRC on emerging economies by looking at the performance of research teams for at least three reasons. First, as in many developing countries, it experiences a rapid process of institutionalization of the scientific and technological community thanks to policies that prioritize the creation of research groups as a legitimate organizational unit able to promote knowledge production with the support of public funding (Orozco et al., 2013). Second, also as most emerging economies, these teams have become increasingly international (Ordóñez-Matamoros, Cozzens, & Garcia, 2010), mostly due to both private and public policies dedicated to that goal using a variety of tools and resources. Third, as most Science and Technology (S&T)-developing countries, Colombia lacks appropriate amounts of scientists and engineers, infrastructure, investment, and institutional support.

According to Ordóñez (2008), both the rapid institutionalization and internationalization processes of research in Colombia resulted from (1) the leading role played since the 1990s by Colciencias, the Colombian national science foundation, in encouraging higher quality of research by ranking research teams and using this rank to support funding decisions; (2) the process of academic accreditation led by *ICFES*, the Colombian Institute of Higher Education, directed at encouraging the transition of higher education institutions to research-based institutions; (3) the loans contracted with IADB, the Inter-American Development Bank, to fund research and development (R&D) and innovation activities as well as masters and doctoral education; (4) the increased market competition resulting from the opening of the economy to foreign products and services; and (5) the increased interaction between the Colombian S&T community and their foreign partners following former international relations (via PhD training abroad and the attractiveness of the country to foreigners due to its rich natural and cultural endowments).

As proof of the fast research institutionalization process taking place in Colombia, it suffices to compare the number of researchers affiliated to a formal research group recognized by Colciencias in 1996 and in 2016: it, indeed, rose from 3,128 to 9,946

Table 1. 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. Ordóñez et al. (2010).

(OCyT, 2016, p. 85), one of the fastest growing communities in the region mostly due, inter alia, to a well-supported policy aiming at doctoral training across the globe.

Furthermore, as Orozco et al. (2013) reveal, the institutionalization of research groups in Colombia implied important increases in scientific production. According to OCyT (2017, p. 145), while in 2007 the number of papers published by authors affiliated to Colombian institutions in journals indexed in the Web of Science was 1,712, in 2016, this number soared to 9,021, again one of the fastest growth levels in the region.

In fact, while Chile was able to duplicate the production of research papers in the Scopus database between 2003 and 2010 allegedly as a result of policies aimed at funding specific projects, Colombia increased its production five times over the same period, arguably due to policies recognizing permanent groups using strict quality standards (Cancino et al., 2014, p. 387).

Regarding the internationalization process, despite the fact that Colombia lacks appropriate numbers of scientists and engineers, infrastructure, investment, and institutional support (Lemarchand, 2010; Vestergaard, 2005), with very low investment on R&D as a proportion of GDP (historically less than 0.3%), the international visibility of its research teams has increased steadily during the last decades, with IRC explaining a large portion of this phenomenon (Ordóñez-Matamoros et al., 2010). According to Ordóñez et al. (2010), as shown in Table 1, which contains the most updated data on the topic available, the proportion of articles published in collaboration with foreign partners grew constantly between 1980 and 2010. Since the 1990s the number of such articles published in high quality journals outnumbers those written without international collaboration, where, according to Fernández, Gómez, and Sebastián (1998), most of the collaborations take place with partners located in the United States and in Europe.

Moreover, as Ordóñez et al. (2010) show, the number of countries with which Colombian scientist collaborates is continuously increasing, both from the Northern and lately from the Southern countries. This is in fact consistent with findings by Wagner and Leydesdorff (2006) and NSF-NSB (2010). Moreover, Lucio-Arias (2013) using the ISI Web of Science between 2001 to 2010 remarks that more than 70% of scientific output in fields like natural sciences, medicine, engineering, and agriculture was produced with IRC, particularly with the United States. Using Scopus, Cancino et al. (2014) found that IRC for Colombia, between 2003 and 2010, represented near 50% of scientific output.

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 decades (Ordóñez, 2008). We will explore in more detail the effects of these two types of collaboration on the performance of the Colombian research teams as will be explained later.

One of the reasons causing this trend of emerging economies increasingly collaborating internationally is provided by Luukkonen, Persson, and Sivertsen (1992), who claim that “scientists who come from scientifically peripheral countries are likely to find few, if any, colleagues in their own country [where,] in order to avoid isolation, they have to look for partners [and resources] from other countries” (p. 104), and since “the less developed the scientific infrastructure from a given country, the higher the tendency for international co-authorship collaboration” (Luukkonen et al., 1992, p. 123). Moreover, as Hwang (2008) states “the struggle over reputation and emulation drives international collaboration, when scientific actors and organizations, even in the case of those from the center, cannot find national alliances” (p. 129).

According to Williamson (1979, 1991), the value added by knowledge and technology means that organizations that will perform better, could engage in inter-organizational hybrid forms of governance, where specific assets mean the power to steer the creation of collaborative networks to achieve better performances.

Previous works by Ordóñez et al. (2010), on the Colombian system, show that international collaborating teams (defined as teams with members publishing in co-authorship with researchers located overseas) are more likely to contribute to local knowledge than comparable noncollaborating teams; and found that a team’s odds of involving the term “Colombi*” in their research process (article titles and abstracts) are 2.2 times larger for those collaborating internationally than for those of comparable characteristics not doing so (Ordóñez et al., 2010). Moreover, a study on the performance of the top ten Colombian research institutions, Ordóñez (2005) found that those co-authoring with partners located in foreign countries tend to publish their work in journals of higher impact factor² and receive more citations per article than those not co-authoring with partners located overseas.

This paper attempts to contribute to the current understanding of the issue by addressing this precise question:

To what extent does North–South and South–South collaboration (defined in terms of both foreign researchers formally affiliated to Colombian teams, and teams working on projects funded by foreign institutions) explain differences in the performance of research teams in emerging economies like Colombia in terms of productivity and local orientation of research?

The following section aims to present the arguments found in the literature that address the relationship between IRC and productivity, as well as between IRC and impact on local knowledge.

Theoretical Debate and Hypotheses

Research collaboration is commonly associated with creativity (Burt, 2004; Levine & Moreland, 2004), scientific productivity (Beaver, 2001; Landry, Traore, & Godin, 1996; Lee & Bozeman, 2005), research quality (Katz & Hicks, 1997; Rigby & Edler, 2005),

innovative capacity (Belderbos, Carree, & Lokshin, 2004; Georghiou, 1998; Tsai & Ghoshal, 1998), the creation of science and technology human capital (Bozeman & Corley, 2004; Rogers, 2000), the consolidation of research agendas (De Greiff & Nieto, 2005; Kumar & Jan, 2013), the expansion of research areas and disciplines (Zhai, Yan, Shibchurn, & Song, 2014), and ultimately, the development of new or better processes, products, and services (Kitagawa, 2010).

However, despite this optimistic outlook, research collaboration is also associated with negative impacts on almost the same aspects, that is, on research productivity (Fox & Faver, 1984; Landry & Amara, 1998); output quality (Herbertz, 1995; Kleinman, 1998); innovative capacity (Gelijns & Thier, 2002); human capital (Behrens & Gray, 2001; Slaughter, Campbell, Holleman, & Morgan, 2002); and relevance of the research (Florida, 1999; Kleinman, 1998; Sagasti, 2005). Some of the risks and costs associated include the “privatization” and “capture” of traditional “public” knowledge (Argyres & Liebeskind, 1998), the “commodification” of knowledge and of human capital (Lincoln, 1998), and the loss of research autonomy (Fox & Faver, 1984).

In the next section, we will discuss in more detail the effects of IRC on both research team productivity and orientation. Some hypotheses will be drawn with an emphasis on the role played by different types of partners (Northern versus Southern) and of collaboration modality (hosting foreign team members versus working with foreign funding).

IRC and Research Productivity

The arguments found in current literature and policy debates in support of the claims that IRC has either positive or negative effects on research productivity, and that such effects vary depending on the characteristics of the partner can be organized in the following family of arguments: (1) the “more is better” family of arguments, which comes in two variations: the “complementarity-based-on-diversity” (or the “strength-of-weak-ties” arguments), and the “complementarity-based-on-similarity” (or the “organizational isomorphism” arguments); (2) the “transaction cost” family of arguments; and (3) the “linear model” argument.

First, there is the “more-is-better” type of arguments, which are to some extent based on the Resource Dependence Theory (RDT) proposed by Pfeffer and Salancik (1978), which argues that more relations, especially with similar actors and actors that belong beyond the local threshold, can lead to achieving better performances. This statement has been formulated for firms and boards of directors and is supported by several empirical results (Davis & Cobb, 2010; Nienhüser, 2008, for reviews). In the case of IRC, the main basis of this argument is proved by the evolution of scientific thresholds that results from the interaction between several researchers in different countries that organized research programs to compete and promote their findings (Lakatos, 1980). As Kuhn’s approach (1962) implies, the increase of IRC leads to the construction of paradigms that impact scientific production and visibility of results. In fact, IRC can give local scientists and engineers access to new knowledge and research resources they would not otherwise have within their national boundaries (Wagner, Brahmakulam, Jackson, Wong, & Yoda, 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 and resources brought about by international

partners to create similar research capacities. These benefits can hardly be obtained in isolation from the global science and technology system. This “family of arguments” claims (implicitly or explicitly) that more actors involved in the research process would involve more bibliographic outputs. In Beaver’s (2001) 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” (p. 369). As the author notes, “like the advantages (...) of parallel processing, one can parcel out parts of a problem, and finish more rapidly than one’s competition” (Beaver, 2001, p. 369).

In Latin America, according to Vessuri et al. (2014), research groups that collaborate internationally have more probability of publishing in international scientific journals, no matter if the collaboration is between North–South or South–South countries (p. 652).

Hence, based on these arguments, we propose our first hypothesis:

H 1 In Colombia, research teams with IRC (regardless of the type of partner or the collaboration modality) have more bibliographic products than teams of similar characteristics that do not collaborate internationally.

A variation of this family of arguments comes from those highlighting the role of diversity to explain qualitative improvements or gains obtained from IRC. In this case, we identify the sort of “strength of weak ties” argument found in Granovetter (1983) and Burt (2004). Levine and Moreland (2004), for whom human cognition is an interpersonal as well as an intrapersonal process, claim that research collaboration increases creativity particularly when it involves some degree of diversity, which may stimulate divergent thinking. According to Allen (1977), 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. Reagans and Zuckerman (2001) found that research collaboration beyond organizational boundaries enhances research productivity, as the need to access better technologies and advanced knowledge lead to seeking out IRC as a resource to improve the local capacity to research and perform better. According to Luukkonen et al. (1992), this is particularly true regarding scientifically peripheral countries (p. 104). Barjak and Robinson (2008, p. 33) found that the diversity created by IRC enhances the research performance in life sciences due to the integration of different cultures, which are able to share resources to create more valuable knowledge.

The set of assumptions highlighting the role of diverse epistemologies gives ground to a new set of comparisons: the effects of IRC whenever it involves partners from Northern and Southern countries. For this reason, we elaborate specific hypotheses for each case.

Based on this variation, which we call the “complementarity-based-on-diversity” argument, we propose our second research hypothesis:

H 2 Colombian research teams collaborating with partners from Northern countries (i.e., hosting researchers from foreign origins) are more productive than comparable research teams not collaborating with researchers from such countries.

A second variation to this first “more is better” family of arguments, is an argument we call the “complementarity-based-on-similarity” argument. This argument is rooted in the literature on sociology of science that considers partner characteristics. Based on this argument, collaborative research is more productive when it involves partners that are compatible in many respects. This argument states 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 affirms that personal empathy in terms of gender, age, social status, origin, language, ideology, experience, professional practice, professional ethos, religion, and so forth, is decisive. As Levine and Moreland (2004) claim, similarity among partners may facilitate communication and interaction, and thereby, creativity: “creativity 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” (Levine & Moreland, 2004, p. 166). To Farrell (2003), 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” (p. 11). The facility of doing research with similar researchers that share common cultural backgrounds, interests, and problems, enhances their capacity to deal with resources, managerial issues, and processes to create knowledge. The regional agreements between Southern countries give support to reduce research costs, promote mutual understanding, and steer efforts to work on local issues and similar problems (Binka, 2005; Boshoff, 2010; Russell et al., 2007).

This argument is also found as a derivation of the Organizational Institutional Theory proposed by Scott (1995) and DiMaggio and Powell (1983). This theory states that organizational isomorphism, the process in which one organization tries to imitate another that has achieved legitimacy, has been pursued to gain recognition and resources to survive. The theory highlights the process in which social actors become similar due to institutional pressures developed by law, accreditations, and certifications, and most importantly, through social acceptance in a cultural setting. Then, the imitation process is more available between organizations that share similar backgrounds, cognitive processes, common standards, and cultural identities. From this perspective, South–South IRC as well as North–North IRC represents an advantage to creating knowledge and achieving better research performance.

Therefore, based on this new variation of the “more-is-better” family of arguments, we propose a third hypothesis:

H 3 Colombian research teams that collaborate with partners from the Southern hemisphere have more bibliographic products than comparable Colombian teams that do not collaborate with partners from the South.

The second family of arguments are counter-arguments to those described above. They can be grouped as part of an overarching “transaction cost argument,” which is used to explain negative effects of IRC. These arguments come, of course, from the Transaction Cost Theory of Williamson (1985), which states that more relationships involve the establishment of more coordination and control mechanisms that

ultimately reduce the performance capacity because of the increase in transaction costs for organizations. The rationality for efficiency between markets and hierarchies proposes that networks encompass several shortcomings to performing common work (Gibbons, 2010). Katz and Martin (1997) claim that research collaboration increases costs of 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, and administrative systems, rules on intellectual property rights, rewards systems, and promotion criteria (Katz & Martin, 1997). Therefore, in light of this theory, in principle, less IRC represents more productivity, or as Landry and Amara (1998) and Cummings and Kiesler (2005) found, more actors in research collaborations, mean sometimes poorer scientific performance. Barjak and Robinson (2008) recognize that the diversity of IRC “rise to additional costs, as people from different cultural backgrounds may speak different languages, attach different significance to concepts and research questions, and have been taught different norms for research procedures and so forth, placing burdens on communication and consensus formation” (pp. 33–34).

Furthermore, one could also argue that, given the relative lack of organizational capacities already characterizing emerging economies (including lack of punctuality, informality of the routines, adverse institutional or even national contexts, and so forth), transaction costs involve a higher burden when partnerships include members from Southern countries. In this case, one would, therefore, expect that negative effects resulting from transaction costs outweigh positive productivity gains resulting from diversity or similarity complementarities in the cases of IRC involving partners from emerging economies.

For these reasons, based on this family of arguments, a fourth hypothesis would read:

H 4 Colombian research teams hosting partners from the global South are less productive than comparable research teams hosting (or not) partners from the global North.

In this case, H4 contradicts H3, where only one of these hypotheses can be true.

Furthermore, it can be claimed that the different effects of collaborating with different types of partners based on their origin (Northern or Southern) is not enough to explain team performance, and that the form such collaborations take (either working with foreign funding or hosting partners from foreign countries) also matters.

Allegedly, research performance improves within favorable funding environments (Auranen & Nieminen, 2010), including foreign funding, especially when it involves developing countries, where resources for research are typically scarce (Ordóñez, 2008). Moreover, Latin American countries actually present low collaboration among themselves as observed in international scientific publications, since they appear to be more engaged in IRC with Northern partners, especially from Europe and the United States (Russell et al., 2007; Sancho Lozano, Morillo Ariza, De Filippo, Gómez Caridad, & Fernández Muñoz, 2006). In the case of Colombia, some interviews carried out by Ordóñez (2008) reveal that IRC represent a crucial channel to conduct research in the cases of health sciences as developed in the Universidad del Valle, where malaria research heavily depends on access to key test materials and devices, personal exchange, and funding from the foreign partners.

We cannot plausibly elaborate *ex ante* specific hypotheses crossing partner's origins and types of collaboration, however. But we do claim that a particular type or modality of collaboration does affect team performance in a positive way.

In this sense, the "linear model" argument claims positive effects of IRC as it sees the collaborative process as an input-output relationship, where foreign funding results in more productivity. It differs from the "more is better" argument as it sees a more deterministic relationship between efforts and results. Based on this argument, one can hypothesize that working with foreign funding leads to greater team productivity. Hypothesis 5 would then read:

H5 Colombian research teams that receive foreign funding have more bibliographic products than teams that do not receive this type of funding.

IRC and Research Orientation

The literature on the impact of IRC on the orientation of research performed (in either developed or emerging economies) is surprisingly silent. The reasons why there are few studies on this issue may be that it is usually hard to define, operationalize, or account for the concept of "orientation" or "relevance" implicit in this issue. In fact, given the intrinsic characteristics of the scientific activity and its outcomes, it is hard to judge whether a specific contribution to knowledge is "relevant" or not, particularly in the short term. Questions such as "for whom?" or "when?" are, indeed, 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 (or even social) development (Cozzens, Popper, Bonomo, Koizumi, & Flanagan, 1994; Kuhn, 1962).

Nevertheless, from the public policy perspective, the issue of "relevance" or "pertinence" is a constant matter of concern both in developed and emerging economies, for example, knowledge for what? (Polanyi, 2000; Smith, 2011). Indeed, as any other human activity that typically demands large support from governments, the performance of science and technology activities is perceived to have the "moral obligation" to make effective contributions to the betterment of the societies that sponsor their activities (Cozzens, 1999a, 1999b; Cozzens et al., 2005). This is particularly true regarding developing countries, where there are more needs and less resources, demanding, therefore, more responsive, relevant, accountable, and legitimate investment on STI activities (Bortagaray & Ordonez-Matamoros, 2012; Kuhlmann & Ordonez-Matamoros, 2017; Ordóñez-Matamoros, Centeno, Arond, Jaime, & Arias, 2018). At the global level, this discussion is related with the call made by, for example, the European Union to address the "Grand Challenges for Society" via its Framework Programmes, and the Millennium Goals, and more recently the Sustainable Development Goals at the United Nations Level, or what is called "Responsible Research and Innovation," in the framework of the Horizon 2020 Programme.

Regarding IRC, 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. Despite the positive and negative impacts of IRC on research productivity as discussed in the previous section, it can also affect other

important aspects such as research autonomy, and even worse “distract,” “detour,” or “deviate” local capabilities and critical mass needed to face local concerns, forcing researchers to address “irrelevant” issues (Sagasti, 2005) or falling into what in the policy literature is called a “type three error”: solving the “wrong” problems (Kuhlmann & Ordóñez-Matamoros, 2017; Ordóñez-Matamoros et al., 2013). In political debates in some developing countries, “irrelevant knowledge” is said to result from policies and strategies aiming at ranking universities and salary of researchers on the basis of indicators that favor the publication of articles in “high impact journals” (Q1 or Q2), which tend to be mainly written for Anglo-Saxon audiences, dealing with typical Anglo-Saxon types of problems, and that sometimes value more quantitative (evidence-based) research than qualitative or narrative and alternative views, hardly observable in quantitative manners. This issue is, unfortunately, still understudied.

We argue this debate is particularly important in the case of emerging economies, where local endowments of S&T capabilities and the stock of local knowledge are remarkably scarce. This concern is consistent with the literature that sees knowledge as an opportunity for development, and development as freedom (Cozzens, Gatchair, Kim, Ordóñez, & Supnithadnaporn, 2008; Sen, 2000). In this framework, the hope is, therefore, that by doing R&D activities in these emerging economies, 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 unexpected ways and in the long run.

The opposite may, therefore, 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 even better.

Similar to the analyses discussed above, the type of partners seemingly affects team orientation differently. Positive effects of South–South research collaboration include the orientation of research to work on issues that are relevant for the Southern countries. The assumption is that locals in such countries can get a better understanding

Table 2. Hypotheses to Test

Hypothesis	Argument
<i>H1: In Colombia, research teams with IRC have more bibliographic products than teams of similar characteristics that do not collaborate internationally</i>	The “more-is-better” family of arguments, some of which are based on the Resource Dependence Theory
<i>H2: Colombian research teams collaborating with partners from Northern countries are more productive than comparable research teams not collaborating with researchers from such countries</i>	The “more-is-better” family of arguments, with a variation to acknowledge the “strength-of-weak-ties” and the “complementarity-based-on-diversity” arguments
<i>H3: Colombian research teams that collaborate with partners from the South have more bibliographic products than comparable teams that do not collaborate with partners from the South</i>	The “more-is-better” family of arguments, with a variation to acknowledge the “complementarity-based-on-similarity” and the “organizational isomorphism” argument
<i>H4: Colombian research teams collaborating with partners from the global South are less productive than comparable research teams collaborating (or not) with partners from the global North</i>	High transaction costs argument
<i>H5: Colombian research teams that receive foreign funding have more bibliographic products than comparable teams that do not receive this type of funding</i>	The “linear model” argument
<i>H6: Colombian teams collaborating with the global South contribute more to local knowledge than those collaborating with the global North</i>	The “outsourcing” or “brain-drain-without-mobility” argument

of their problems by working on issues that are common to partners with similar characteristics in all relevant aspects.

In contrast, negative effects of collaborating with international partners on research orientation may be based on the existence of a relationship characterized by subordination. This could be particularly true when there are no bounds of some sort (contractual, personal, and so forth) that lead to a commitment to work on local issues in/on developing countries.

In practice, Northern researchers may be interested in working with peers from developing countries because of their calculations of the quality/price ratio. In addition, researchers from the South may be tempted 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. We can call this the “outsourcing” or “brain-drain-without-mobility” argument.

Our final hypothesis aims, therefore, at testing this underlying idea:

H 6 Colombian teams collaborating with the global South contribute more to local knowledge than those of similar characteristics collaborating with the global North.

To summarize, the following are the six hypotheses to empirically test (see Table 2), as inspired from the existing literature and political debates on the topic. For this purpose, we will rely on data on research teams’ practices in Colombia:

As can be seen in Table 2, hypotheses contradict themselves somewhat. Taken together, we see scenarios that are theoretically possible. What then is to be found? What arguments or theories are then to be supported or rejected by data? In the following section, we will discuss the ways we addressed the aforementioned exploratory hypotheses empirically, based on exceptionally rich data on Colombian research team activities available for a specific period of time.

Methodology

We use Colombian data and look at the performance of its local research teams both in terms of productive capacity and of the orientation of the research performed. The analyses are done on cross-sectional data of 1,889 Colombian research teams active between 2003 and 2005 working in all scientific fields. A database was built from the official national S&T databases CvLAC and GrupLAC,³ which are developed and managed

Table 3. Sampling Strategy Based on Team Characteristics

Total teams registered in 2005 by Colciencias	3,342
Teams excluded (of which)	1,453
<i>Teams created in 2005 (i)</i>	6
<i>Teams with less than two R/E active^a by 2003 (ii)</i>	919
<i>Teams with no R&D projects active^b btw 2003 and 2005 (iii)</i>	1,172
Teams used in the analysis of the sample ^c	1,889

Note: (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.

^aAn active R/E is a Researcher or Engineer that reports research activities done in 2003 or before.

^bAn active R&D project refers to R&D work reported as being in progress between 2003 and 2005.

^cSums do not add up due to double counting of teams’ attributes.

since 1996 by Colciencias, the Colombian science and technology policy organization. These databases capture detailed information on both researchers (CvLAC) and research teams (GrupLAC) willing to be recognized as such by Colciencias and benefit from its policies. Such metrics are also widely used for administrative and strategy making purposes both by universities and other types of research and policy organizations in the country. The databases provide information on the projects and several types of results in terms of products and services that are evaluated by Colciencias to assign recognitions and funds. The information used in this research is, therefore, of high quality and has been subject of several quality controls due to their important (and contested) implications for both individuals and institutions in the country.

In the framework of this paper, the unit of analysis is the research team, which is defined as (1) two or more people who claim they work together on common research problems or interests; (2) who are recognized by their home institution and Colciencias as such; (3) work on at least one R&D project actively during the period of observation; and (4) produce research outputs jointly or independently that are attributed to team work.

Table 3 presents the sampling strategy this research is based upon, in which 1,889 teams were analyzed. The sample represents 56% of the total teams registered in 2005 by Colciencias.

In this study, team performance is measured by the productivity of the teams in terms of their bibliographic production and their revealed capability to contribute to local knowledge. We refer to productivity as the total amount of outputs (bibliographic products), where a multiplier effect is calculated as a result of collaborating internationally.

Bibliographic outputs refer to either one of the 19 types of scientific products identified in the databases.⁴ Team contribution to local knowledge is measured based on whether the team works on issues involving the word “Colombi*”⁵ as a proxy for research orientation appearing either on the title of their R&D projects, on the title of the products, on the abstracts or on the keywords of their scientific outputs. We claim that this way, one can observe research team orientation and relevance in a plausible manner, as it reveals circumstances where the research done contributes to the local stock of knowledge available, either because it uses Colombia as the unit of analysis or as a research space or laboratory. According to Whittaker (1989), words in titles, keywords, and abstracts provide the main representation of the content and the orientation of the bibliographic product. Furthermore, we claim that, given the relatively low visibility of research involving Colombia in the time the data were analyzed, authors would had been inclined to specify the cases involving Colombia.

IRC is measured in two ways: foreign researchers affiliated to local research teams, and foreign funding. 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 specific/attributional ways international research collaboration affects research team productivity and their contribution to local knowledge in Colombia.

Table 4 summarizes the selected variables to analyze the effects of IRC on team productivity and on team orientation.

Table 4. Description of Variables

	Variables	Description
1. Team productivity	<i>Total bibliographic products</i>	An interval-level variable for the number of bibliographic products the team done between 2003 and 2005
2. Team orientation	<i>Projects or products with "Colombia"</i> ^a	1 if the team used "Colombia" in the title of an R&D project or product or in the corresponding abstract, 0 otherwise
3. International research collaboration	<i>IRC North</i> (foreign researchers affiliated to local research teams or funding)	1 if the team had foreign researchers or foreign funding between 2003 and 2005 from Northern countries, 0 otherwise
	<i>IRC South</i> (foreign researchers affiliated to local research teams or funding)	1 if the team had foreign researchers or foreign funding between 2003 and 2005 from Southern countries, 0 otherwise
	<i>People from the North</i>	1 if the team had foreign researchers between 2003 and 2005 from Northern countries, 0 otherwise
	<i>People from the South</i>	1 if the team had foreign researchers between 2003 and 2005 from Southern countries, 0 otherwise
	<i>Funding from the North</i>	1 if the team had foreign funding between 2003 and 2005 from Northern countries, 0 otherwise
	<i>Funding from the South</i>	1 if the team had foreign funding between 2003 and 2005 from Southern countries, 0 otherwise
4. Research team characteristics	<i>Core</i>	An interval-level variable for the number of researchers and technicians the team had in 2003
	<i>Age</i>	An interval-level variable for how long the team had been in existence in 2003 ^e
	<i>Total PhDs</i>	An interval-level variable for the number of members with PhD degree the team had in 2003
5. Scientific field ^a	<i>Total projects</i>	An interval-level variable for the number of R&D projects the team had active in 2003
	<i>Health sciences</i>	1 if the team works in the field of health sciences, 0 otherwise
	<i>Agricultural sciences</i>	1 if the team works in the field of agricultural sciences, 0 otherwise
	<i>Social sciences</i>	1 if the team works in the field of social sciences, 0 otherwise
	<i>Humanities</i>	1 if the team works in the field of humanities, 0 otherwise
	<i>Engineering</i>	1 if teams the team in the field of engineering, 0 otherwise
	<i>Business Sector</i>	1 if the team works in the business sector, 0 otherwise
	<i>Government Sector</i>	1 if the team works in the government sector, 0 otherwise
6. Sector ^b	<i>Other Sector</i>	1 if the team works in another sector, 0 otherwise
7. Institution size ^c	<i>Small institution</i>	1 if the team works in a small institution, 0 otherwise
	<i>Medium institution</i>	1 if the team works in a medium institution, 0 otherwise
	<i>Small city</i>	1 if the team works in a small city, 0 otherwise
	<i>Medium city</i>	1 if the team works in a medium city, 0 otherwise

^aTeams working in the field of natural sciences are the reference group.

^bTeams working in the academic field are the reference group.

^cTeams working in big institutions are the reference group.

^dTeams working in big cities are the reference group.

^ePlease notice that we use "team age" as a proxy of team expertise, since we do not know the years of experience of the team members considered individually.

In addition, 20 semi-structured interviews and several presentations in academic events were done with team members and STS scholars to provide the qualitative information needed to assess the plausibility of the models and of the results, and to better interpret the findings and their implications.

Finally, standard robustness check techniques were applied to correct for heteroscedasticity in the case of the multiple regression analyses, and to assess the quality of the matching algorithm used in the nonparametric analyses.⁶

IRC and Team Productivity

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)⁷ to predict counts in a highly skewed distribution. The ZINB model is used when the outcome “0” is due to two different processes (Long & Freese, 2006): as the result of the lack of possibilities to produce or the lack of motivation to produce. The models are:

$$\begin{aligned} \text{ZINB totbibprod 05} \\ = \alpha + \beta_{1\text{IRC}N05} + \beta_{2\text{IRCS}05} \\ + \beta_{3\text{to }6}\text{ResearchTeamCharacteristics} + \beta_{7\text{to }11}\text{Field} \\ + \beta_{12\text{to }14}\text{Sector} + \beta_{15\text{to }16}\text{InstitutionSize} \\ + \beta_{17\text{to }18}\text{CitySize} \end{aligned}$$

The Propensity Score Matching (PSM) approach is used to control for selection bias using counterfactuals. This approach was implemented following Caliendo and Kopeinig (2008).

IRC and Team Orientation

To account for the effects of international research collaboration on a 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).

Table 5. Impact of Different Types of Collaboration on Team Productivity: ZINB

	ZINB	
	%	Count
IRC	29	2.66**
IRC with North	11	1.57
IRC with South	46	3.35**
People from North	-7	-0.24
People from South	32	1.91**
Funding from North	20	2.12*
Funding from South	52	4.99**

Note: Observations: 1889. % change in expected count for unit increase in X.

*We can observe a statistical significance at 1% level.

**We can observe a statistical significance at 5% level.

The following models are used:

$$\begin{aligned} & \text{Logit } ppkeycol05 \\ & = \alpha + \beta_1 IRCN05 + \beta_2 IRCS05 \\ & \quad + \beta_3 \text{to } \beta_6 \text{ResearchTeamCharacteristics} + \beta_7 \text{to } \beta_{11} \text{Field} \\ & \quad + \beta_{12} \text{to } \beta_{14} \text{Sector} + \beta_{15} \text{to } \beta_{16} \text{InstitutionSize} \\ & \quad + \beta_{17} \text{to } \beta_{18} \text{CitySize} \end{aligned}$$

The PSM approach is also used in this analysis to control for selection bias using counterfactuals as explained later.

Results

IRC and Team Productivity

As Table 5 shows, International Research Collaboration has an important impact on team productivity. In fact, the expected count of bibliographic products of collaborating teams is 29% higher than that of comparable noncollaborating teams. In terms of products, collaborating internationally increases expected productivity count by 2.66. This result confirms our first hypothesis: teams with IRC have more bibliographic products than comparable teams that do not collaborate internationally, therefore providing evidence supporting the “more-is-better” argument.

This result is supported by many team leaders interviewed who founded it plausible, as they tend to see foreign researchers affiliated to local research teams as people much more organized, better prepared, and goal oriented than Colombian researchers. According to an interviewee, “I prefer to work with foreign researchers rather than with local researchers because they are more respectful of the intellectual property of what is being produced by the team. Their contribution to the team may take some time to materialize but it is always positive.”

Surprisingly, hosting researchers from the North is not associated with greater team productivity. In fact, IRC with the North seems to have no significant effect on teams’ production. This partially contradicts our second hypothesis and the associated “strength-of-weak-ties” and the “complementarity-based-on-diversity” arguments. This could be related in great part to the transaction costs of this particular type of collaboration. As one interviewee claimed, sometimes teams spend too much time and resources trying to “accommodate” such researchers.

Conversely, IRC with the South (regardless of the modality) can increase bibliographic production by 46%. Moreover, teams who host researchers from the South produce almost two more products than those teams of comparable characteristics who do not. These results are consistent with our third hypothesis: collaborative research is more productive when it involves partners that are compatible in many senses, therefore confirming the “more-is-better” family of arguments, and its variation of “complementarity-based-on-similarity” and the “organizational isomorphism” arguments. The reasons why horizontal collaboration shows greater impact on team productivity than vertical collaboration may be associated with the fact that teams

working in countries with similar characteristics, types of problems, and level of S&T development are in a better position for overcoming the transaction costs typically present in a collaborative enterprise. Looking at the research issues from a similar perspective, partners are more familiar with what may contribute to their productivity. As a consequence, the fourth hypothesis, based on the “transaction cost” argument, is not supported in the case of South–South collaboration. As rightly highlighted by one of the reviewers of this article, it is important to acknowledge that there might be teams in the South that resemble very much in many respects teams in the North and vice versa. Although we are not able to assess such claim, which we find totally valid, we acknowledge such weakness but still feel confident making the claims made as far as we are looking at overall patterns found in a relatively large sample of almost 1,900 research teams working in Colombia. This can also help to explain some of the paradoxes found and reported.

Regarding our fifth hypothesis, we found empirical support for the “linear model” hypothesis: teams receiving foreign funding are more productive than teams that are not funded by other countries. Moreover, we found that having funding from the North increases by 20% teams’ productivity, which results in a rise of 2.12 bibliographic products. But results reveal that having projects funded by institutions from the global South can increase the number of products by 52%, which means that expected productivity counts increase by almost five products when the funding comes from Southern countries.

According to one of the scientists interviewed, the difference found can be explained by “the motivation of countries to fund research.” Funding from Northern countries are sometimes donations, where the supporting institutions do not expect to get anything back from their funding, and therefore, do not require the publication of research results. However, funding from Southern countries often involves the matching of local funds and the research they support is commanded for specific purposes. Also, such sources typically have stricter control systems, mostly due to lack of confidence and measures in place for closer accountability (to avoid corruption, which is more frequent in Southern countries than in Northern countries). This type of collaboration, via funding for research, one can claim, is therefore more likely to require the production of bibliographic products.

Table 6. International Research Collaboration and Team Contribution to Local Knowledge: LOGIT

	LOGIT	
	% (1)	% (2)
IRC	30.3**	6.0**
IRC with North	51.9*	9.6*
IRC with South	0.8	0.2
People from North	14.3	3.1
People from South	-17.5	-4.2
Funding from North	50.0*	9.4*
Funding from South	23.7	4.9

Note: Observations: 1889. % (1) change in odds. % (2) changes in predicted probabilities for Colombi* in production or project.

*We can observe a statistical significance at 1% level.

**We can observe a statistical significance at 5% level.

IRC and Contribution to Local Knowledge

Regarding the effects of international research collaboration on team orientation, and contrary to the findings related with team productive capacity, collaborating with partners from the global South (regardless of the modality) does not appear to be significantly associated with team contribution to local knowledge as shown in Table 6.

Contrary to our sixth hypothesis, we found that it is working with partners from the global North that results in positive effects on a team's likelihood to contribute to local knowledge. In fact, the odds of a team involving "Colombi*" in its research (the project, title, the product title, their abstracts, and so forth) are 1.5 times larger for those working with partners from the North than for those of comparable characteristics that do not. This finding, therefore, contradicts the "outsourcing" or "brain-drain-without-mobility" arguments. We acknowledge that the use of the word Colombi* as proxy of research team orientation can imply some shortcomings. It could be the case that local orientation of a research can be found, for example, in titles that mention Amazonas or Bogota, not Colombia. This limitation can be overcome in future research including other words like the names of the main cities, regions, departments, and probably national organizations in Colombia. We claim the reader must do a confident interpretation in terms of the direction of the effects reported recognizing the limitation of the proxy used in this research.

Finally, as Table 6 shows, we can affirm that this effect is mostly a consequence of working with funding from these Southern countries. This may have to do with the fact that contract research in/with the North do a better job in monitoring local relevance of the research funded than similar types of contracts with Southern country institutions. No association was found between a team's contribution to local knowledge and whether or not the team hosted a foreign researcher.

Conclusion and Policy Implications

IRC appears to have great potential for contributing to narrowing 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 IRC is positively associated with both research team productive capacity and team ability to contribute to local knowledge in Colombia. Based on this finding, we can confidently conclude that IRC, if broadly practiced by most Colombian research teams, would significantly contribute to national scientific and technological capabilities, as defined by more productivity and more research done on local issues.

Moreover, we found that the type of partner seems to matter for boosting local S&T capabilities in developing countries. In the case of Colombia, we found that collaborating with partners from the South yields the greatest impact on team productive capacity, and that collaborating with Northern countries contributes the most to team ability to add to local knowledge.

Indeed, the fact that collaborating with partners from the South yields the greatest impact on team productive capacity can be explained by the complementarity-based argument in terms of the alienation of common goals, the awareness of the same

types of issues, similar epistemological understanding of the matters addressed, and relatively more commitment toward increasing their visibility, and toward maximizing their relative lack of resources. Having said this, one would expect that governments in developing countries promote more South–South IRC than what is currently the case in order to increase their research team productivity.

However, these findings provide partial evidence to support the research hypothesis proposed regarding the diversity arguments. We hypothesized that collaborating with Northern countries yields positive impacts on team productivity, but this relationship was found to be statistically not significant. Possibly one explanation as to why this hypothesis was not supported is because research teams from Colombia expecting to access rich research resources (asset specificity as it is called in transaction costs economics) from Northern countries do not manage in the end to achieve such goals. In this sense, Boshoff (2010) claims that, according to Dahdouh-Guebas et al., many researchers in African and Latin American countries tend to “participate in projects that have been conceptualized and designed by the partners in the North, meaning that the African-based researchers are just part of the execution. In their view, North–South relationships tend, therefore, to be highly unequal, and it is not uncommon for Southern collaborators to even be completely ignored as co-authors in the eventual publication” (p. 487). Having said this, and if this suspicion is true, governments in developing countries should promote the negotiation of research agendas between peers regardless of the origin of the partners to ensure equal access to research assets and publication rights.

Also, we found that, despite the fact that we hypothesized that working with partners from Southern countries would have positive results on a team’s probability to involve Colombia in its research process, this was also not supported by the data. We neither have a plausible explanation nor policy recommendation based on this finding, which makes it a good topic for future research.

Nevertheless, this hypothesis was confirmed for collaborations with partners from Northern countries since working with partners from those countries is positively associated with a team’s likelihood of working on local issues. We suspect that this is due to the fact that researchers from the Northern countries typically find the type of problems and research resources found in the South as both inspiring and particularly rich because they do not exist in the North. Furthermore, this finding reveals particularly true regarding foreign funding from the North, which in fact contradicts the claim discussed earlier that Northern countries “outsource” research done in Southern countries presumably taking advantage of the relatively favorable quality/cost ratio. Therefore, these results provide strong support for policies aiming at the internationalization of the local scientific communities involving funding and alliances with Northern countries.

Finally, we established that not only the type of partner matters, but also the type of collaboration for explaining research team performance in Colombia. In this respect, regarding the linear-model hypothesis, we found that when IRC is based on working with foreign funding, research team productivity increases despite the origin of the partner. Interestingly, receiving funding from the South appears to have greater effect on research team productivity than working with funding from Northern sources. This can be explained by the fact that South–South collaboration typically implies

shared resources, increasing the pressure to publish, whereas North–South collaboration often involves resources granted without the pressure to publish (grants as aid). From the policy perspective, it is interesting to confidently affirm that encouraging research teams to work with foreign funding from Northern countries not only positively affects team productivity, but also team orientation to work on local issues. This cannot be clearly said regarding the funding from Southern countries. Another possible recommendation is to make sure funding conditions between Southern countries include some goal requirements in terms of research performance.

Equally interesting, we did not find any association between the team's choice to host foreign researchers from Northern countries and its research performance. In contrast, when teams host researchers from Southern countries, their productivity increases, but not their orientation toward local issues. This calls for the need to revise the rationale and operation behind exchange programs designed to increase researcher inbound mobility, as high transaction costs may be keeping those teams from harnessing foreign capabilities. Teams require more support from their institutions in logistical issues, so that they can focus more on R&D. This is definitely a finding worth exploring further, both for academic and policy interests.

In sum, governments may make substantial contribution to team output and ability to contribute to local knowledge by facilitating international collaboration and in so doing by encouraging higher standards of member quality. In this sense, we believe that there are several ways IRC can be facilitated. For instance, financing the researchers' doctoral studies abroad may have a high impact on the decision to collaborate internationally (Barjak & Robinson, 2008).

Moreover, according to one of the interviewees, sometimes the main reason for not collaborating internationally is because of the lack of public support. This leads to the conclusion that what Colombian teams need is more support to engage with foreign partners and members with PhDs, more funding for the performance of R&D activities, and leaders with foreign educations who are able to write in a second language. The internationalization process of the Colombian scientific community is evidently under way, despite the fact that the country is among the smallest investors on R&D in the region with respect to its GDP. This is a paradox worth exploring further, where the hypothesis is that it is due to the successful implementation of relatively inexpensive private and public policies as the ones discussed in the introduction.

In terms of general policy implications, it is important to highlight that the promotion of IRC (be it via encouraging more PhDs earned abroad, funding researchers' mobility, and so forth) instead of promoting local collaboration could end up creating gaps between research teams across disciplines and subnational regions. This is an outcome that, in one way or another, should be avoided or counterbalanced with complementary policy strategies, even though Colciencias, for example, does not make funding decisions based on whether the proposal involve IRC but on the quality of the proposals themselves.

Last but not least, we acknowledge that to better substantiate the conclusion as to the fact that IRC has great potential for improving team performance, and more importantly the process through which this happens, a more in-depth research based on case-study methodology could be a good complement. This may address one of the claims made by one of the reviewers in the sense that there may be Southern countries' teams that behave as Northern ones and vice versa. These sorts of complexities

are sources of ideas for new and needed studies aiming at better understanding science, technology, and innovation theory; policy and practice across the globe; and especially when they involve cases in emerging economies (Kuhlmann & Ordóñez-Matamoros, 2017)).

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Notes

- 1 The authors acknowledge that the classification of countries between “North” and “South” can be controversial. The division between North and South countries is based on information from the World Bank, in terms of their income per capita. This logic is used in studies that address North–South research collaboration (see for example Gaillard, 1994; Melon et al., 2009).
- 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 (higher quality) the journal is assumed to be.
- 3 These databases can be accessed at www.colciencias.gov.co. Look for the “Scienti Platform” link in the institution’s main webpage to access the information. They can also be accessed directly at <https://scienti.colciencias.gov.co/gruplac/>.
- 4 Bibliographic products include 19 types of products: paper in scientific journals, summary in scientific journals, survey in scientific journals, clinical trial in scientific reviews, memories in conference proceedings, summary in conference proceedings, published book, chapter in a published book, edition, research book, preface, epilogue, presentation, introduction, working paper, research reports, databases for research, and biological collections with systematized information.
- 5 In the Discussion section, we do acknowledge some limitations of this approach, however.
- 6 A detailed description of the implementation of the techniques used can be found in Ordóñez (2008).
- 7 We performed an electronic search to identify methodological techniques used to assess the impact of IRC yielding 51 references published in journals such as *Higher Education*, *International Journal of Technology Management*, *Lancet*, *Minerva*, *Organization Science*, *Research Evaluation*, *Research Policy*, *Scientometrics*, *Technological Forecasting and Social Change*, and *Technovation*. The methodologies used by the authors of such papers are mainly based on bibliometric indicators, review of co-authored articles over a determined period of time, and social networking analysis. No article was found using ZINB models, however.

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