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Interdisciplinarity and research on local  
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country

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# Interdisciplinarity and research on local issues: evidence from a developing country

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## Abstract

This paper examines the role of interdisciplinarity on research pertaining to local issues. Using Colombian publications from 1991 until 2011 in the Web of Science, we investigate the relationship between the degree of interdisciplinarity and the local orientation of the articles. We find that a higher degree of interdisciplinarity in a publication is associated with a greater emphasis on local issues. In particular, our results support the view that research that combines cognitively disparate disciplines, what we refer to as distal interdisciplinarity, is associated with more local focus of research. We discuss the policy implications of these results in the context of national research assessments targeting excellence and socio-economic impact.

Keywords: interdisciplinary research; S&T capabilities; local knowledge; research assessment; excellence, socio-economic impact.

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## 1. Introduction

It is widely assumed that research addressing social and economic challenges is best conducted through interdisciplinary approaches (Rhoten and Parker, 2006). The perception of the benefits of interdisciplinary research (IDR)<sup>1</sup> has stimulated a steadily growing interest in developing new knowledge through research that integrates the skills and perspectives of multiple disciplines. The heightened growth of such research

[may] be in part a parallel of the wider societal interest in holistic perspectives that do not reduce human experience to a single dimension of descriptors, and to awareness that a number of extremely important and productive fields of study are themselves interdisciplinary: biochemistry, biophysics, social psychology, geophysics, informatics... (Aboelela et al. 2007, p. 330).

This article aims to add to the body of literature on the role of IDR to address complex social, cultural, economic and political issues by empirically examining the relationship between IDR and the production of local-issue research. By local-issue research we mean research related to local contexts, conditions or topics; in this inquiry, research that is pertinent to a whole country, Colombia.

The central hypothesis of this article is that local-issue research is more interdisciplinarity than non-local research. This link is important because local-issue research is frequently used to contextualise knowledge that is socially relevant. Our focus on a particular place is supported, among others, by Barry, Born & Weszkalnys (2008) who have asserted that IDR (more below) and the importance of the “context of application as a site for research... at which knowledge is produced” (p. 21) need to be accounted for when examining the contributions of research to society. The relationship between local-issue research, problem-oriented research, socially relevant research, applied research and interdisciplinarity is unclear and we do not aim to unpack it in this article. We would like, nevertheless, to reflect on their entangled relationships with the purpose of highlighting why looking at IDR and local-issues matters in science policy.

Scholars have increasingly recognized the need to link disciplinary fields on the axiom that IDR is more able to respond to pressing societal questions or to deal with a particular problem. For instance, health may not be adequately studied through a single disciplinary framework. Instead, poor health results from a constellation of factors: malnutrition, bad eating habits, genetics, age, poverty, ignorance, pollution, environmental conditions, and peer pressure (for instance, in anorexia).

Insights on the relation between IDR and problem-solving have been substantiated by recent quantitative studies. In general, there are diverse bodies of literature on social or cognitive diversity in groups or in network relations, which have shown a positive relationship between such diversity and problem-solving and/or creativity outcomes (e.g. Page, 2007, Fleming et al, 2007). Specifically for research, D’Este et al. found that researchers with disciplinary diversity are more likely to “exploit their technology inventions and produce saleable goods and services” (2012, p. 301). In a separate study D’Este et al. (2013) also concluded that cognitive diversity is associated with “pro-social” research behaviour, that is, attitudes that explicitly take into account the social relevance as a critical goal of research. In studies specifically about IDR, Rijnsover and Hessels (2011) found that researchers’ experience in firms and governments increases the likelihood that they will engage in interdisciplinary collaborations while it decreases the likelihood of mono-disciplinary collaborations. Similarly Carayol and Thi (2005, p. 77) reported that connections with industry is strongly correlated with interdisciplinary research.

Gibbons et al. (1994) and Nowotny, Scott and Gibbons (2001) observed that science is undergoing a shift from a Mode-1 production of science, which is mainly disciplinary and initiated by the interests of the researcher, to a Mode-2 which is interdisciplinary, that displaces “a culture of

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<sup>1</sup> We use the term interdisciplinary research to mean all different types of cross-disciplinary research (multi-, inter- and transdisciplinary research).

autonomy of science” (p.89) and addresses socially relevant issues. As Barry, Born & Weszkalnys (2008) noted, “what is novel is the contemporary sense that greater interdisciplinarity is a necessary response to intensifying demands that research should be integrated with society and the economy” (p. 23).

Concomitantly, IDR has received direct support in recent years through public policies as a means of fostering the social relevance of research, endorsing that such research strengthens, renews and interweaves issues that largely deal with science, technology, society, economics and innovation. This affirmation may be seen in Science Technology and Innovation (ST&I) policies in which IDR has ostensibly come to be regarded as an essential component. Examples of documents that mirror this can be found in, among others, reports by the OECD, UNESCO (Godin, 2009), the UK Royal Society, research funding agencies, such as the U.S. National Science Foundation (Adams and Clemons, 2011: 218), National Institute of Health and UK Research Councils<sup>2</sup>, government agencies and universities (Brint, 2005).

Despite the apparent acknowledgement of the benefits of IDR, scholars have found that IDR is, in practice, discouraged in a variety of ways. One way is found in the research assessment practices that many countries have implemented. These assessment exercises are based on disciplinary perspectives (see special issue edited by Laudel and Origi, 2006; Martin, 2011; also a review in Rafols et al., 2012). This disciplinary emphasis has tended to encourage academics to publish in disciplinary journals with the potential result of jeopardizing more interdisciplinary “risky research” that may yield greater social and economic impacts (Nightingale and Scott, 2007, pp. 546-547, Smith et al. 2011). In universities, a prevailing ‘silo’ mentality also tends to discourage IDR, a behaviour that is arguably helped on by the research assessment exercises. Such an attitude may hinder the ability to address future ‘grand challenges,’ such as smart cities and aging, issues that many governments consider as national priorities and are related to local-issue research.

The structure of the paper proceeds as follows. First, we provide an overview of the research on IDR and the significance of local context in promoting IDR. Then we present an overview of the policy context for IDR in Colombia. The fourth section explains our methods: operationalization of local-issue research, measures of interdisciplinarity as diversity measures and logistic regression. Section Five presents the results. We observe a positive relationship between IDR and the production of local-issue research. Section Six discusses the results and section Seven explores the policy implications of these findings. We make available to the readers the original data, results of the analysis and computational procedures in three Supplementary Files.<sup>3</sup>

## **2. The relationship between IDR and local-issue research**

According to the extant literature on the contribution of IDR to a range of public and “real-life” issues and abiding with the importance of context (in our case, a developing country Colombia) in such research, IDR can be expected to play an important role in the development of local S&T capabilities. Already noted above, its importance is further illuminated below:

Necessity and complexity have also been cited as reasons for IDR in and about developing countries. Shinichi Ichimura cautioned that the conceptual frameworks of traditional disciplines are often too narrow and too compartmentalized for the study of problems in other areas. Norman Dinges made a similar observation about cross-cultural research, suggesting interdisciplinary perspective grows as the “indigenization” of research sensitive to local norms takes place; and Lawrence Murphy, using the

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<sup>2</sup>A recent call by the UK Economic and Social Research Council, the Arts and Humanities Research Council and the Defence Science Technology Laboratory, an agency of the UK Ministry of Defence, is indicative of the need for integrative approaches: “Science and security – linking social science, arts and humanities to understand the impacts of science and technology on defence and security”.

<sup>3</sup> Supplementary Files are also available at [www.interdisciplinaryscience.net/pub\\_docs/idr-local-files/](http://www.interdisciplinaryscience.net/pub_docs/idr-local-files/)

example of the Social Research Center of the American University of Cairo (Egypt), has traced the movement from narrow, academically oriented research projects to more appropriate long-term interdisciplinary, multifaceted studies that analyzed problems of immediate concern to the host nation. (Klein, 1990, p. 45)

Scholars have also argued that local contexts are enablers of IDR because they require different cognitive approaches to understand and address their specific needs:

Practical contexts also have aspects that combine perspectives from different disciplines and are seldom intelligible without the development of novel inter-, multi- or transdisciplinary modes of knowledge production. (...) Localized science (...) is not just a 'perturbation' of the claims of universally valid paradigms or a denial of the feasibility of generalizing, reducing and deducing anything and everything. Knowledge production in the context of application is itself a fertile seedbed for the emergence of novelty. Localized investigations create genuine new knowledge. They can be full of surprises, especially when they combine knowledge elements from different realms, and mix them with societal expectations. (Nowotny and Ziman, 2002).

The importance of 'localized' research has been also highlighted by Stiglitz (among others, such as Bones et al. 2011 and Gahi 2004), who pointed out that "local researchers combining the knowledge of local conditions – including knowledge of local political and social structures -- .....provide the best prospects for deriving policies that both engender broad-based support and are effective..." (Stiglitz, p. 24 in Stone, 2000). Specifically for developing countries, the production of locally relevant interdisciplinary knowledge is considered key for achieving what has been called the "indigenization of science", which results from the selection, adaptation, application, localization and combination of theories and methodologies from different sciences (Alatas, 1993: 312).

In summary, on theoretical grounds and based on anecdotal evidence, one can formulate the hypothesis that there is a positive relationship between IDR and the production of local-issue research. Furthermore, given that solving local issues such as agricultural production demands knowledge from very different disciplines, one can think that the type of IDR required for local-issue research consists of the combination of distant disciplines such as atomic physics, neuroscience and sociology. This is what Yegros-Yegros et al. (2013) have called *distal interdisciplinarity*. This stand in contrast to *proximal interdisciplinarity*, which is mainly focused on one discipline and takes some insights from neighbouring disciplines – for example a neuroscience study that had contributions from related disciplinary categories such as physiology, pharmacology and clinical neurology.

In our empirical examination of the relationship between IDR and the production of local-issue research, we operationalise these concepts drawing on publication data from journal articles, reviews and proceedings papers indexed by the Web of Science (WoS). First we chose the presence of the country name ("Colomb") in the abstract or titles as the criterion to identify locally oriented research. Place-names act both as a coordinate system that locates geographically the action being performed and as a characterizing device that sets the action within a specific socio-economic context (for a conceptualization of place-names as indexical and characterizing signs, see Keates, 1996, pp. 81-82). Place-names "are of such vital significance because they act so as to transform the sheer physical and geographical into something that is historically and socially experienced" (Tilley, 1994, p. 18). This approach was inspired by a recent publication by Ordóñez-Matamoros, Cozzens and Garcia (2010).<sup>4</sup>

Second, following the National Academies (2005) we define interdisciplinarity as the integration of knowledge and operationalise it through the use (i.e. integration) of bibliographic references from diverse disciplinary categories in one article. Then, we gauge the degree of interdisciplinarity using

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<sup>4</sup> In a quick examination of the use of a "place-name" we found that the percentage of publications that mention the country in their title, keywords or abstracts is much higher in Latin American countries, for instance, Colombia, Brazil, Argentina, Chile and Mexico, than in developed countries such as the U.S., the Netherlands, Germany and the UK. For the former group of countries, papers accounted for 15% to 25% of their total production, whereas for the developed countries the percentage was below 5%.

recently developed bibliometric indicators (Porter and Rafols, 2009), i.e. measuring the diversity of disciplines in the references, where the diversity is computed taking into account the number, balance and disparity among the disciplines (Stirling, 2007).

Third, we use a multivariate test to find whether there is a significant relationship between degree of IDR in a publication and the production of publications on local issues. We use two types of control variables: (1) degree of collaboration, given that collaborations tend to be more interdisciplinary (Qin et al., 1997) and that locally oriented research is likely to be more collaborative as well. (2) discipline of the publication, given that the degree of interdisciplinarity is highly dependent on disciplines (Porter and Rafols, 2009) and some disciplines such as ecology or public health are obviously more context-oriented than disciplines such as physics or computer sciences.

We run this test with a composite measure diversity first, and later unpacking the various dimensions of diversity, which allows distinguishing distal versus proximal types of interdisciplinarity.

### **3. Context: the case of Colombia**

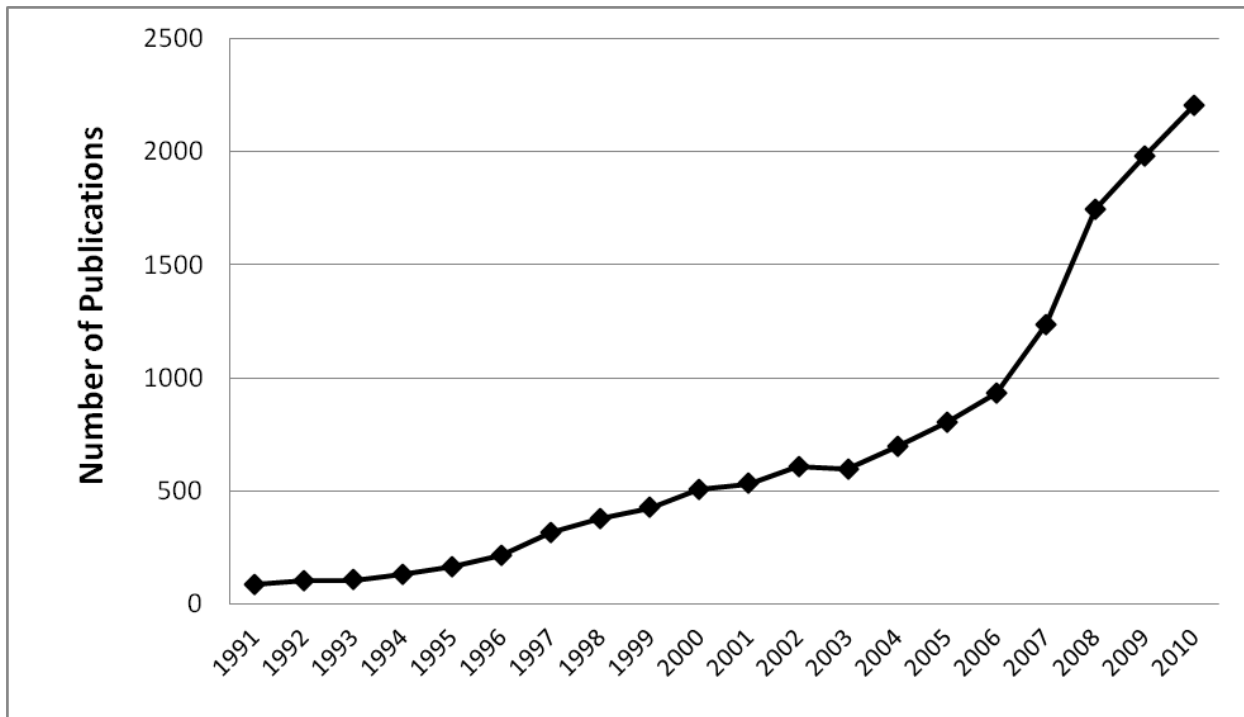
Colombia is a country of approximately 45 million inhabitants (CIA, 2013) which recently has been steeply increasing its number of scientific publications (Lemarchand, 2012, p. 294). Figure 1 shows the publications in the WoS in the last two decades.<sup>5</sup> As an upper middle income country, Colombia is making efforts to improve its science and technology system. To do so, policies have been put in place in order to incentivise excellent research, which is often evaluated in terms of bibliometric indicators (e.g. citation impact).

The interest of Colombia as a case for investigating local-issue research is that it is unclear that its economic fabric will benefit from research that is perceived as excellent from an international perspective (Todt et al., 2007). In other words, in developing countries such as Colombia, the lack of alignment between excellence and socially relevant research is more acute. Given lack of quantitative measures on social relevance, we use degree interdisciplinarity is an intermediate variable that suggests potential relevance. A brief review of Colombia's science policy in the last two decades reveals that IDR has been associated with local-issues and social relevance.

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<sup>5</sup> Increase in Scopus is even steeper, from 1,000 in 2002 to more than 6,000 in 2012.

**Figure 1. Number of publications with a Colombian address in Web of Science over time**



In Colombia Colciencias is the organization that plays the lead role for the promotion and support of ST&I. Although originally created in 1968 mainly as a funding agency for research, it evolved into the central public organization for the formulation of national ST&I policy. IDR directed at socially relevant issues is explicitly promoted in the structure and operation of Colciencias, and these are reflected in its policies. For example, the organization has encouraged interdisciplinary collaboration between researchers, students and technicians among the research groups.

Colciencias also regularly issues open calls for projects, which are for the most part problem-oriented<sup>6</sup> and in some cases are offered jointly with companies that require research in their field (oil and energy, for example). Other programmes that expressly mention the support of IDR are the promotion of Centres of Excellence, which are interdisciplinary networks of groups based on national strategic areas (Colciencias, 2004), and the support of Centres of Technological Development, which are private Industrial Technology Research Institutes, centres for agricultural research and other centres in cross-cutting technologies. The ambition of promoting IDR is also reflected in Government's strategic policy documents. For example, in 2000 the "Departamento Nacional de Planeación" (National Planning Department) required explicitly that the Centres for Technological Development create interdisciplinary and inter-institutional innovation networks in order to propose and implement projects for technological improvement in Colombian firms (República de Colombia - DNP, 2000, p. 18). Also, in 2002, the National Development Plan of the Government included "the strengthening of National Research Programs and their joint action articulated in complex topics and national priorities that require interdisciplinarity" (República de Colombia, 2002, 120).

At Colombian universities, which have been trying to develop their research capabilities, one can also find policies supporting IDR. For instance, the Universidad Nacional de Colombia (the largest

<sup>6</sup> We acknowledge that problem-oriented research can also be undertaken in a disciplinary context. For instance, the problem of reconciling quantum mechanics with relativity in string theory. However, for the purposes of this article, we treat problem-oriented research in terms of IDR.



public university) and the Universidad de los Andes (private) specifically mention support for IDR both in their mission statements and through calls for interdisciplinary projects (Universidad Nacional, 2005).

Despite these measures by Government and universities, it remains unclear how the implementation of those policies is fostering the development of IDR. Instead, the encouragement for IDR appears to end with simply the formation of the aforementioned interdisciplinary groupings. An example of this can be seen in the assessment of research groups that is carried out regularly by Colciencias. This assessment exercise ranks research groups in terms of bibliographic outputs that are based on a disciplinary perspective derived from publication patterns found in physics, for instance, that is being applied indiscriminately to all research groups regardless of their area of research (Ruiz et. al., 2010; Restrepo and Villegas, 2007). As a result of an over-emphasis on the production of articles, researchers and universities participating in collaborative interdisciplinary groups, continue to focus on conducting disciplinary research (Chavarro et. al., 2010).

Colciencias also has acknowledged that it continues to operate through disciplinary lenses, for instance, in its internal structure for funding (discipline-based national programmes) and policy making. In 2004 there was a proposal to modify its internal structure to reflect a more problem-oriented outlook (República de Colombia – Colciencias, 2004b). Although it was not finally approved, for reasons that remain unknown, the proposal illustrates Colciencias' awareness that a genuine modification of the organizational structure may be needed to achieve its stated goals for IDR, as noted above. While some initiatives have been developed, such as in encouraging the formation of collaborative interdisciplinary research groups, in practice, institutional inertia and operational practices remain important barriers to IDR.

These observations lead us to conjecture that the Colombian IDR policies in the main are, to date, declaratory, that is, the policies are mainly public statements without specifying the actions to be taken to implement their IDR policies. In summary, it is uncertain that the degree of IDR has been significantly affected by these policies.

## **4. Methods**

### **4.1. Data and Sample**

The dataset is comprised of articles, reviews and proceedings papers included in Thomson-Reuters' Web of Science (WoS) Database. These articles are authored by at least one researcher who was affiliated to a Colombian institution at the time of publication. We include records from 1991 (one year after the official foundation of the Colombian System of Science and Technology and the designation of Colciencias as the institution in charge of ST&I policy in the country) to 2010. All original data, analytical results and associated graphs are made available to readers in Supplementary File 1.<sup>7</sup> We only take into account records with more than three bibliographic references successfully categorized into WoS Categories (this was necessary to construct a reliable measure of IDR). The application of these filters yielded 14,402 records.

### **4.2. Variables and Methods**

#### *Operationalisation of local-issue research*

We define research orientation as “local” when it directly mentions a word starting with “Colomb” in the topic (title, abstract or keywords) and “non-local” when it does not (1 means “local” and 0 “non-local” orientation).

In order to test the robustness of the method used as a proxy to identify local-issue research, two of

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<sup>7</sup> [http://www.interdisciplinaryscience.net/pub\\_docs/idr-local-files/data\\_and\\_graphics\(1\).xls](http://www.interdisciplinaryscience.net/pub_docs/idr-local-files/data_and_graphics(1).xls)

the authors manually coded as locally oriented or not, two samples of 100 papers identified by the algorithm as local and non-local respectively. Articles which related to Colombian topics such as locally relevant diseases (such as Chagas), plants (such as oil palms) or related materials (such as fique fibers) were classified as local. The individual examination involved making a dichotomous judgement of the degree of local orientation vs. the degree of “universality”. Among the 100 articles classified as local, only 2 were perceived as non-locally oriented by both examiners, and 10 by at least one examiner (false positives). Among the 100 articles classified as non-local, 9 were coded as locally oriented by both examiners and 26 by at least one examiner (false negatives). These results show that the classification of articles in locally oriented is problematic, but that the method used is an acceptable proxy for a large scale study such as this (in the range of about 5-10% false positives and about 10-25% false negatives). Of course, such degree of error would not be acceptable for research assessment.

### *Operationalisation of degree of interdisciplinarity*

Degree of interdisciplinarity of a publication is estimated by the diversity of WoS categories in its references, an indicator ranging from 0 to 1 (1 indicates totally interdisciplinary and 0 completely disciplinary). To do so, we follow Yegros-Yegros et al. (2010, 2013) (see also Rafols et al. 2012), who use each of the dimensions of diversity (variety, balance and disparity) separately as well as a synthetic measure of diversity (Rao-Stirling’s) which combines all three dimensions (Stirling, 2007).

The equations for each variable of diversity are found below:

*Variety* =  $v$  = Number of WoS categories

$$Balance = \frac{1}{\ln(v)} \sum_i p_i \ln p_i$$

*Disparity* =  $\frac{1}{v(v-1)} \sum_{i,j} d_{ij}$ , sum only for those categories in the reference set.

$$Rao - Stirling Diversity = \sum_{i,j} p_i p_j d_{ij}$$

where  $v_{max}$  = variety of the article with a greater number of WoS categories identified within the dataset,  $p_i$  = proportion of elements in category  $i$ ,  $d_{ij}$  = distance between categories  $i$  and  $j$  (Rafols and Meyer, 2010, p. 267).

Each of the variables captures a different aspect of the general concept of diversity (Stirling, 2007, p. 710), but we should emphasize that there are other possible forms to operationalise the same properties.

*Variety* corresponds to the number of categories in which elements can be classified. *Balance* describes the evenness of the distribution of elements into categories. A sample is completely balanced if all categories share the same number of elements. *Disparity* is used to reflect the degree of the distinctiveness that exists between the elements of the distribution. If classifications are a means to separate elements, disparity is a relational property that tells the extent of separation (the distance) between the categories used. For example, soprano voices are closer to mezo-soprano than to contralto voices in terms of tone range. For this, a value for distance between elements (a metric) has to be set.

*Rao-Stirling* diversity (also known as ‘quadratic entropy’) captures these three dimensions into a single indicator. It was first proposed as an ad-hoc measure of IDR by Porter et al. (2007) (the ‘Integration score’), which was then further conceptualized by Rafols and Meyer (2010). The key advantage of this measure is that it not only takes into account the distribution of references across

disciplinary categories, but crucially also considers how cognitively distant these categories are. Intuitively, this means that a publication with references from atomic physics and cell biology is weighted as more interdisciplinary than one with references from cell biology and biochemistry.

The cognitive distances  $d_{i,j}$  between categories are drawn from the metrics underlying the global maps of science done by Rafols et al. (2010) on journals in the WoS for 222 WoS Categories (formerly Subject Categories) in 2007.<sup>8</sup> Each measure of diversity is calculated for each article by classifying bibliographic references into one or more WoS Categories, using the software Vantage Point.<sup>9</sup>

The attribution of references to WoS Categories is very inaccurate –there is up to 50% disagreement between alternative classifications (Rafols and Leydesdorff, 2009, p. 1828). As a result, the diversity measure of a single article has a large noise and is not reliable, but the robustness of global science maps suggests that the error is not systematic, and with large numbers, one can still obtain good approximations (Rafols and Leydesdorff, 2009, p. 1829). As our sample consists of 14,402 publications, we are confident that the aggregation will yield reliable results. After classifying the references, a procedure in the statistical language R<sup>10</sup> was run on a list of articles to compute the indicators. These scripts in R are available in Supplementary File package 3.<sup>11</sup>

### *Control variables*

In addition, we incorporated two control variables that may have effects on the relationship: these are (i) Collaboration and (ii) Field to which an article is more likely to belong, for instance Biosciences or Social Sciences. The variable Collaboration is a dummy variable with the categories International collaboration, National collaboration and No collaboration. This variable was identified from the field “C1” in the WoS format, which holds the affiliation data of authors.

The categorical variable for Field (“Macro-discipline”) aims to control how the cognitive context may influence the local or non-local nature of the outcomes of research given that some disciplinary fields can be more prone to producing local studies than others (for example. environmental studies tend to be more local than chemistry). The construction of this variable is based on the results of Rafols et al. (2010). Using factor-analysis, WoS Categories were classified into 18 ‘Macro-disciplines’ according to similarity in citation patterns.<sup>12</sup> We assigned articles to the list of 18 macro-disciplines by selecting the discipline with the highest number of references in a given article. Table 1 shows a description of all the variables.

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<sup>8</sup> The similarity matrix between Web of Science Categories is available at Loet eydesdorff’s webpage for making overlay maps: <http://www.leydesdorff.net/overlaytoolkit/> and at [http://interdisciplinaryscience.net/pub\\_docs/idr-local-files/classification\\_of\\_journals.xlsx](http://interdisciplinaryscience.net/pub_docs/idr-local-files/classification_of_journals.xlsx)

<sup>9</sup> [www.thevantagepoint.com](http://www.thevantagepoint.com)

<sup>10</sup> <http://www.r-project.org/>

<sup>11</sup> [http://www.interdisciplinaryscience.net/pub\\_docs/idr-local-files/script/](http://www.interdisciplinaryscience.net/pub_docs/idr-local-files/script/)

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**Table 1: Description of the variables used in the study**

Name	Type	Values	Role	Description
Research orientation	Categorical	1 = local 0 = non-local	Dependent	If an article has the word Colomb* in the title, abstract or keywords, it is considered local
Variety	Numerical	Between 1 and 222	Independent	Number of Web of Science Categories cited by each article.
Balance	Numerical	Between 0 and 1	Independent	Balance in terms of proportion of references in each Web of Science Categories cited by an article.
Disparity	Numerical	Between 0 and 1	Independent	Average distance between the Web of Science Categories cited by an article. Distances are given by cross-citations between Web of Science Categories across all science.
Rao-Stirling Diversity	Numerical	Between 0 and 1	Independent	This variable synthesizes three properties of disciplinary diversity: variety, balance and disparity.
International Collaboration	Dummy	0 or 1	Independent	1 if more than one country participates in an article.
National Collaboration	Dummy	0 or 1	Independent	1 if more there is more than one Colombian affiliation
No Collaboration	Dummy	0 or 1	Independent	1 if there is no collaboration (only one address)
Macro-Discipline	Dummy	Agricultural sciences Biomedical sciences Business and Mgmt. Chemistry Clinical medicine Cognitive sciences Computer sciences Ecology Economics & geography Engineering Environmental S& T Geosciences Health services Infectious diseases Materials sciences Physics Psychology Social studies	Independent	This is an aggregation of disciplines in terms of cross-citations made by Rafols et al. (2010). This variable groups articles in terms of their belonging to one of these categories. Each article belongs to one category. The assignation of an article to a category was done by the most referenced discipline in each article.

### 4.3. Regression analysis

To test the relationship between IDR and local research orientation, we used logistic regression. While other techniques, such as discriminant analysis, require meeting strict conditions of multivariate normality and equal distribution of variance and covariance matrices, logistic regression is robust when such conditions are not strictly met (Hair et. al., 2005: 276). For these reasons we have selected logistic regression using the statistical packet SPSS.

The dependent variable is research orientation (that is, whether an article is local or not), and the main predictor is the degree of interdisciplinarity, firstly as a synthetic variable (Rao-Stirling diversity) and secondly as represented by its different constituent dimensions (variety, balance, disparity). Hence, we performed the logistic regression in two blocks, first with Rao-Stirling as independent variable, second with the various diversity dimensions. We also tested for a possible

inverted U-shape relationship between IDR variables and the dependent. The reduction in the -2 log likelihood (the variance) of each model is used as a criterion to assess the improvement in each block. We use three Pseudo-R<sup>2</sup> measures to assess the adequacy of the models. The first measure is Hosmer and Lemeshow's R<sup>2</sup>, the second Cox and Snell's R<sup>2</sup> and the third Nagelkerke's R<sup>2</sup>. These measures calculate the variation that is explained by the model based in -2 LL. The first is calculated as -2LL (new model)/-2LL (original model). 0 means "no improvement" and 1 means "total fit of the model". This measure, however, does not take into account the size of the sample. For that, Cox and Snell's R<sup>2</sup> is used. As this measure cannot reach the theoretical maximum of 1, the correction by Nagelkerke is used. These three statistics help to assess the goodness of fit of the model (Field, 2009: 269).

## 5. Results

Tables 2 and 3 present general descriptive values for each variable in this study. Other graphs and tables can be found in the annex (Supplementary File 1<sup>13</sup>).

As can be observed in Table 2, the dependent variable (local) has about a quarter of the share of the articles, that is, 24% of articles explicitly reference Colombia in their texts as compared to articles that do not mention it. Regarding Collaboration, we observe that Colombian articles in the WoS database are more likely to be carried out in collaboration with authors from abroad. The discipline with more references in this database is Biomedical Sciences and the one with fewer references is Social Studies.

Figure 2 shows that although the number of publications by researchers affiliated to a Colombian organisation in journals covered by WoS has been increasing since 1991 (as previously shown in Figure 1), the percentage of articles focused on Colombia has only slightly decreased from ~30% to ~25%.

Figure 3 provides an initial view of the relationship between Rao-Stirling diversity and local research orientation. In considering the distributions of locally focused publications (black columns) and non-local publications (grey columns) separately, we see that the proportion of local-issue publications is higher for interdisciplinary articles (that is, Rao-Stirling diversity above 0.5), while the proportion of non-local articles is higher for lesser interdisciplinary articles (that is, Rao-Stirling diversity below 0.5).

**Table 2: Descriptive statistics of the categorical variables Research orientation, Collaboration and Macro-discipline.**

	Frequency	%
<b>Research orientation</b>		
Non-Local	10930	75.89%
Local	3472	24.11%
<b>Collaboration</b>		
National	4968	34.50%
International	8749	60.75%
No collaboration	685	4.76%
<b>Macro-discipline (MD)</b>		
Agricultural Sciences	997	6.92%

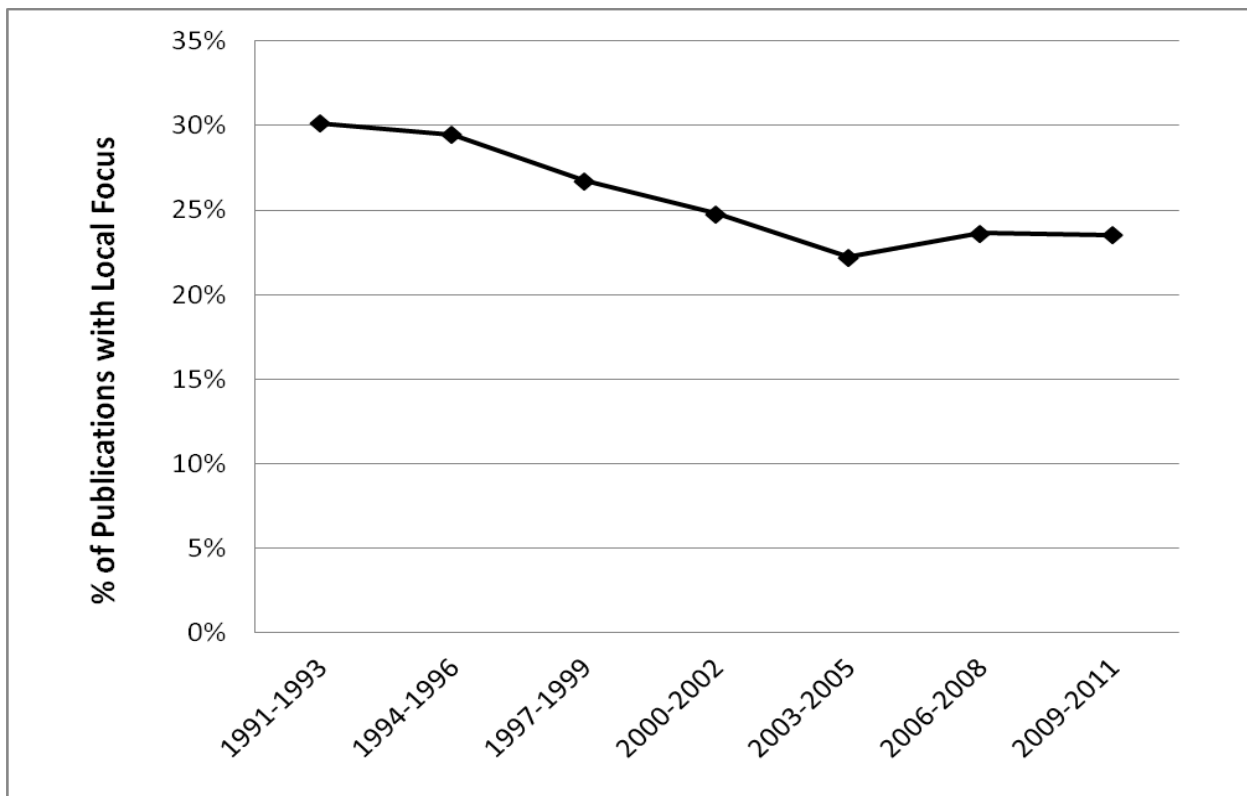
<sup>13</sup> Also available at [http://interdisciplinaryscience.net/pub\\_docs/idr-local-files/](http://interdisciplinaryscience.net/pub_docs/idr-local-files/)

Biomedical Sciences	2305	16.00%
Business and Management	97	0.67%
Chemistry	700	4.86%
Clinical Medicine	1173	8.14%
Cognitive Sciences	705	4.90%
Computer Science	436	3.03%
Ecology	1230	8.54%
Economics and Geography	230	1.60%
Engineering	439	3.05%
Environmental S&T	615	4.27%
Geosciences	334	2.32%
Health Services	353	2.45%
Infectious Diseases	1517	10.53%
Materials Science	1808	12.55%
Physics	1281	8.89%
Psychology	158	1.10%
Social Studies	24	0.17%

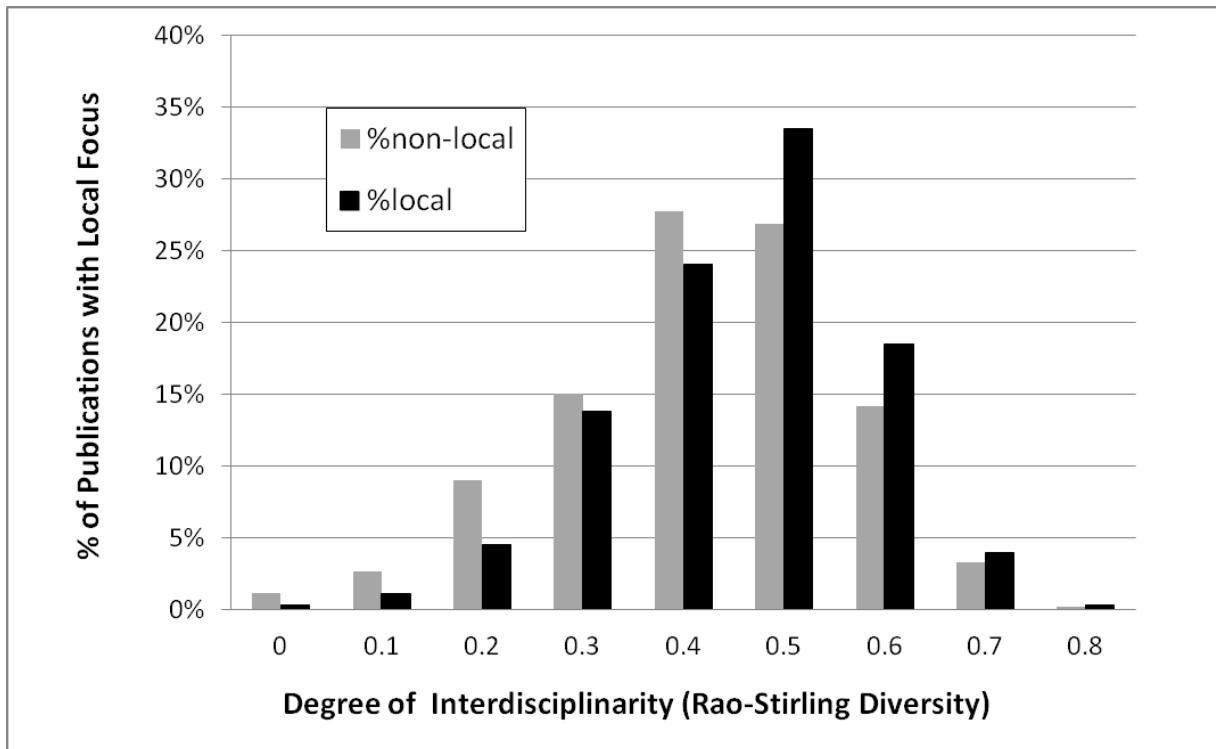
**Table 3: Descriptive statistics of measures of interdisciplinarity**

	Minimum	Maximum	Mean	Std. Deviation
<b>Rao-Stirling Diversity</b>	0.000	0.802	0.429	0.137
<b>Variety</b>	1	43	9.560	4.933
<b>Balance</b>	0.000	1.000	0.813	0.123
<b>Disparity</b>	0.000	0.999	0.629	0.125

Figure 2. Percentage of publications with local focus over time



**Figure 3. Percentage of local and non-local papers with a Colombian address by degree of interdisciplinarity (Rao-Stirling diversity)**



It is worth noting that most of the publications present a Rao-Stirling diversity score between 0.4 and 0.6, that is, they are moderately interdisciplinarity. The distribution of the variable shows a normal curve, within acceptable ranges of kurtosis and skewness (+/- 1) (Bulmer, 1979, p. 63). Extreme cases like publications with very low (0.1) or very high (0.8) Rao-Stirling diversity are unusual. When exploring variety, balance and disparity in regard to research orientation we find that the share of local papers is slightly greater for higher degrees of disparity and balance, whereas for variety it is the opposite (see supplementary file).

An examination of the titles of the top 10 most interdisciplinarity articles according to Rao-Stirling diversity depicts this relationship between IDR and local issues. As it can be seen in Table 4 below, six out of the top ten most interdisciplinarity articles are classified as local and most of them focus on topics directly related to Colombian issues: malaria, fruits, management of agricultural biotechnology in Colombia, and transport. The local paper that appears to be less related to locality is the one about history, but since it is on the history of engineering education, it could be considered as being relevant to the country's technological development. The majority of the 10 articles appear to involve problem-oriented research, with perhaps the exception of the last article, which appears to be more theoretical.



**Table 4. Top 10 most interdisciplinary articles in the sample, grouped by local – non-local.**

Title	Local	Rao-Stirling Diversity	Variety	Balance	Disparity
A method for forecasting the seasonal dynamic of <b>malaria</b> in the municipalities of Colombia	Yes	0.80	12	0.97	0.88
A transport network reliability model for the efficient assignment of resources	Yes	0.80	14	0.98	0.86
Interpretation of <b>commercial production information</b> : A case study of lulo ( <i>Solanum quitoense</i> ), an under-researched <b>Andean fruit</b>	Yes	0.80	26	0.93	0.88
<b>Managing agricultural biotechnology</b> in Colombia	Yes	0.78	26	0.93	0.86
Analysis of <b>Andean blackberry (<i>Rubus glaucus</i>) production models</b> obtained by means of artificial neural networks exploiting information collected by small-scale growers in Colombia and publicly available meteorological data	Yes	0.78	15	0.90	0.88
<b>Engineering Education</b> and the Identities of Engineers in Colombia, 1887-1972	Yes	0.76	8	0.95	0.91
Automatic <b>Detection of Pathological Voices</b> Using Complexity Measures, Noise Parameters, and Mel-Cepstral Coefficients	No	0.79	26	0.91	0.83
Using auxiliary information to adjust fuzzy membership functions for improved <b>mapping of soil qualities</b>	No	0.79	18	0.93	0.87
Entropy production in a radiating layer near equilibrium: Assaying its variational properties	No	0.77	11	0.96	0.83

Note: Measures of Rao-Stirling close to one indicate more diversity. A value of variety of 26 indicates that a publication has published in 26 out of the 222 WoS categories. Higher balance shows more evenness in the distribution of references. High disparity indicates more average cognitive distance between the references.

## Logistic regression

As explained we performed the logistic regression in two blocks. In the first block, we investigated the influence of Rao-Stirling diversity, with Collaboration and Macro-discipline as controls. In the second block, we replaced Rao-Stirling diversity with the set of separate characteristics: Variety, Balance and Disparity. Table 5 presents the results of the regression:

**Table 5. Coefficients of the logistic regression**

Variables	Model 1	Model 2
Rao-Stirling Diversity	0.539 (1.715) **	
Variety		-0.257 (0.945) ***
Balance		1.051 (2.861) ***
Disparity		1.110 (3.034) ***
<b>Controls</b>		
National Collaboration	0.743 (2.101) ***	0.770 (2.161) ***
International Collaboration	0.155 (1.168)	0.227 (1.255) *
<b>Macro-disciplines</b>		
Agricultural Sciences	0.119 (1.126)	-0.025 (0.976)
Business and Management	0.502 (1.653) *	0.263 (1.301)
Chemistry	-1.925 (0.146) ***	-2.104 (0.122) ***
Clinical Medicine	-0.181 (0.834) *	-0.320 (0.726) ***
Cognitive Sciences	-0.187 (0.829)	-0.259 (0.771) *
Computer Science	-1.647 (0.193) ***	-1.943 (0.143) ***
Ecology	1.195 (3.305) ***	1.083 (2.955) ***
Economics and Geography	0.212 (1.236)	-0.067 (0.935)
Engineering	-2.291 (0.101) ***	-2.610 (0.074) ***
Environmental ST	-0.290 (0.748) **	-0.504 (0.604) ***
Geoscience	1.805 (6.079) ***	1.619 (5.047) ***
Health Services	1.409 (4.093) ***	1.249 (3.487) ***
Infectious Diseases	0.586 (1.797) ***	0.589 (1.802) ***
Materials Science	-2.891 (0.056) ***	-3.076 (0.046) ***
Physics	-4.406 (0.012) ***	-4.675 (0.009) ***
Psychology	0.397 (1.487) *	0.291 (1.338)
Social Studies	0.956 (2.602) *	0.746 (2.109)
<b>Constant</b>	-1.627	-2.341
Cox and Snell's R2	0.199	0.207
Negelkerke's R2	0.297	0.309

Note: Odds ratios are shown in parentheses. Model 1 includes Rao-Stirling diversity as a single measure for IDR. Model 2 replaces Rao-Stirling diversity with Variety, Balance and Disparity. The reference category for Collaboration is "No Collaboration" and the reference category for Macro-discipline is "Biomedical Sciences". Collinearity tests and correlations can be found in the annex (Supplementary File 1).

\*\*\* p < .001, \*\* p < 0.01, \* p < 0.05

After running the logistic regression we found that IDR variables (Rao-Stirling diversity --Variety, Balance and Disparity) are related to the production of knowledge on local issues. These relationships are statistically significant. The relationships are as follows. First, Rao-Stirling diversity is positively related to the production of knowledge on local issues. The odds ratio shows that for each unit increase in Rao-Stirling diversity (allowing for Collaboration and Field (Macro-

discipline)) it is 1.7 times more likely that an article is related to local issues.

Second, we found different effects for each of the constituent properties of IDR. Disparity and balance exhibit a positive relationship with the local focus of articles. A unit increase in these variables makes it approximately *three times more likely* that a paper is on local issues. Variety, on the other hand, contributes negatively to this relationship. A unit increase in Variety makes it *0.9 times less likely* that a paper is local.

The positive effect of disparity and balance on research indicates the specific type of interdisciplinarity that matters for tackling local issues: research that bridges across large cognitive distances and that engages significant proportions of distant disciplines. Following Yegros-Yegros (2013), we call this *Distal interdisciplinarity*. On the other hand, the negative effect of Variety suggests that research that builds on many related sub-disciplines but has little Disparity and Balance (what we refer to as *Proximal Interdisciplinarity*) is not related to local problems.

Third, it is important to note that the controls used in this analysis also have significant effects on the predicted variable. National Collaboration and International Collaboration are positively related to the production of knowledge on local issues. National Collaboration increases the probabilities to publish on local issues by about two times, while International Collaboration by 1.2 times.

The relationship between Macro-discipline and the production of knowledge on local issues is reflected in different ways. As compared to Biosciences (used as the reference category), there are some Macro-disciplines that increase the probability of producing publications on local issues. They are Business and Management, Ecology, Geosciences, Health Services, Infectious Diseases, Psychology, and Social Studies. Their odds ratios show an increase in odds between two (Social Studies) and five (Geosciences).

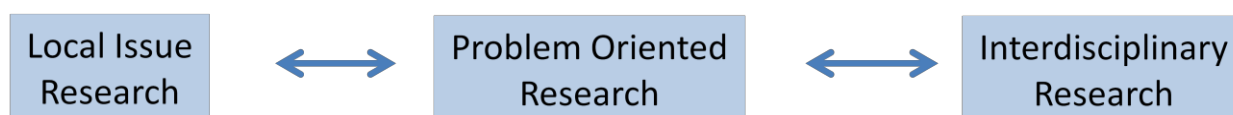
Finally, we tested for inverted U-shape relationships in each of the IDR-related variables. None of the quadratic variables showed a significant coefficient ( $p < 0.05$ ), that is, there is no evidence of an “optimum” level of IDR after which the relationship changes its direction.

## 6. Discussion

The results of our analysis support the hypothesis that IDR is related to the production of knowledge on local issues. As discussed in the Introduction, this result is consistent with conventional wisdom on the relationships between local-issue research, problem oriented research and IDR, as illustrated in Figure 4. The relationships could be explained by the fact that research related to local issues often aims to tackle or address specific problems, and tends to be associated with problem-oriented research. Problem-oriented research as well often requires the mobilization and integration of diverse type of knowledge (Zierhofer and Burger, 2007; Rijnsoever and Hessels, 2011, D’Este et al., 2012), and this cognitive diversity is associated with interdisciplinary approaches (Rafols and Meyer, 2010). It follows that articles on local issues will tend to be more interdisciplinary as a result of their tendency to have a problem-oriented nature. An inspection of the titles of the most interdisciplinary articles of the sample (see Table 4 above) supports this hypothesis. They are related, for example, to health (malaria), transport networks and agriculture (for example, the fruits *lulo* and Andean blackberry).

Our findings also reveal the specific type of interdisciplinarity that is relevant to local issues. We find that articles with a focus on local issues tend to have a more balanced composition of highly disparate bodies of knowledge (more balance and disparity) in their references. An interpretation of these results is that local-issue research is associated with Distal Interdisciplinarity, which can be thought as higher risk, given the difficulties of combining disparate bodies of knowledge. For example, the study looking into the seasonal dynamics of malaria (Table 4 above) is based on insights from public health research, ecological dynamics, and statistical physics modelling.

**Figure 4. Hypothesised relationship between local-issue research, problem-oriented research and IDR.**



Our findings also show, in contrast to Distal Interdisciplinarity, that a high number of disciplinary categories (high variety) is associated with less engagement with local issues. This suggests another type of IDR, Proximal Interdisciplinarity, which has a clear disciplinary focus with some, but limited engagement (low balance) with neighbouring disciplines (low Disparity). Proximal Interdisciplinarity is possibly a more common approach in many fields largely because it is less risky, given that it is easier for researchers to communicate across short cognitive distances. Our study suggests that it is a form of IDR that is less likely to be related to local-issue research.

Our findings, however, come with some methodological limitations. First, different results might be found in high income countries in which the local focus is very likely not to be as evident as in a developing country such as Colombia. However, we think that our results could be generalized to other developing countries, in the so-called “periphery” of the R&D system. These countries are aspiring to participate in the global scientific community, while at the same time, they are trying to adapt and develop knowledge relevant to their local contexts with the aim of appropriating the socio-economic returns of S&T. Second, the study uses a measure of interdisciplinarity that relies on the classification of references into WoS Categories. Given that the classification of articles into WoS categories is very problematic (Rafols and Leydesdorff, 2009) and the number of references in an article is not very high, the measure used is very noisy, that is, it is likely to have variations due to contingent choices in reference selection. Nevertheless, we contend that our sample is sufficiently big to reduce the noise from an inaccurate classification.<sup>14</sup>

## 7. Conclusions and policy implications

This paper has examined the relationship between IDR and the generation of knowledge related to local issues. By using the case of Colombia (based on publication data extracted from the WoS), we have found that IDR publications tend to address local issues more often than disciplinary research does.

Interestingly, the findings of this article stand in contrast to those by Yegros-Yegros et al. (2013) who analyzed the relationship between IDR and citation performance. Yegros-Yegros et al. find a positive influence of variety and a negative influence of disparity and balance on the number of citations per paper (see Table 6 below).

Since the authors’ findings show the exact opposite effects of our findings, as illustrated in Table 6 above, we hypothesise that related relations may be at play: (1) problem-oriented research tends to be associated with cognitively disparate IDR (distal interdisciplinarity); and (2) problem-oriented research (which is related to local-issue research), tends to be less valued in academic terms (less cited) –therefore distal interdisciplinary papers gets less citations. This conjecture echoes what Nightingale and Scott (2007) have hypothesized: “Research that is highly cited or published in top journals may be good for the academic discipline but not for society” (p. 547). Nightingale and Scott’s hypothesis could not be directly tested with the publications examined in this article because

<sup>14</sup> An article-level classification system might provide a more accurate means of measuring the degree of interdisciplinarity (Waldman and van Eck, 2012), but the cognitive distances derived from article-based classification will require validation, whereas the ones we use here are known to be imprecise but have been validated in various studies at sufficient levels of aggregations (e.g. Soós and Kampis, 2011, Rafols et al., 2012).

the diversity of fields and times rendered the normalization of citations uncertain and controversial (Rafols et al., 2012).

**Table 6. Comparison of results**

	<b>Effect on citations (Yegros-Yegros et al. 2013)</b>	<b>Effect on local focus (this paper)</b>
<b>Variety</b>	Positive	Negative
<b>Balance</b>	Negative	Positive
<b>Disparity</b>	Negative	Positive

Drawing together our findings with those of Yegros-Yegros et al. (2013) depicted in Table 6, we suggest that research assessment exercises that aim for “high impact” in terms of citation counts (and possibly in journal ranking as well) may have the likely perverse consequence of sacrificing IDR that could produce local-issue research, which in turn could jeopardize the development of local S&T capabilities. Stated differently, by focussing on improving scientific “excellence” using narrow bibliometric measures such a citations in a developing country context, research run the risk of fostering the de-localization of research.

A potential consequence of lack of local orientation is that the socio-economic benefits from investment in public R&D may not be captured by national or regional actors. This de-localization is a risk not only for developing countries, but also for any relatively peripheral countries or regions. For example, Todt et al. (2007) found that the public research community in biotechnology in the region of Valencia (Spain) is highly developed and has frequently participated in global research networks. However these links were accompanied by the exclusion of the local biotechnology industry, lack of production of appreciable local-issue research. Hence, the benefits of biotechnology research funded by the Valencian government were hardly appropriated by the local biotechnology stakeholders/firms but by international collaborators and multinational companies. In short, public support for biotechnology “excellence” in Valencian universities did not benefit the local biotechnology sector.

In conclusion, the comparison of the results of this paper with those of Yegros-Yegros (2013) suggests that research evaluation aimed at fostering excellence according to citation impact may result in a disincentive for researchers to address local-issues. One can speculate that too narrow a focus on disciplinary-based criteria of research excellence may jeopardise policies aimed at enhancing the socio-economic benefits of research (Rafols et al., 2012).

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## Supplementary Files

In order for readers to gain deeper understanding if desire, we provide further data and methodological details in the Supplementary Files.

- **Supplementary File 1** provides the raw data used in the analysis  
[http://interdisciplinarityscience.net/pub\\_docs/idr-local-files/data\\_and\\_graphics%281%29.xls](http://interdisciplinarityscience.net/pub_docs/idr-local-files/data_and_graphics%281%29.xls)
- **Supplementary File 2** provides further details of the quantitative analyses, including descriptive statistics and support of the robustness of the regression.  
[http://interdisciplinarityscience.net/pub\\_docs/idr-local-files/annex.docx](http://interdisciplinarityscience.net/pub_docs/idr-local-files/annex.docx)
- **Supplementary File Package 3** provides the script and the raw data for the computation of the diversity measures, include the distance metrics between Web of Science Categories  
[http://interdisciplinarityscience.net/pub\\_docs/idr-local-files/script/](http://interdisciplinarityscience.net/pub_docs/idr-local-files/script/)

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