Size of science team at university and internal co-publications: science policy implications

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Abstract

Scientific collaboration within a science team (unit, group, etc.) has been under scrutiny. Recently, science of team science has emerged to use science for deep understanding of the ways researchers jointly perform science to increase their team's performance. This article analyses internal scientific outputs with respect to the size of university's science team. The objective is to examine the science policy motive that is, if the team size increases, by encouraging academics to gather in larger teams, then their outputs increase. The method of the contrapositive of this conditional statement is adopted. Thus, 120 accredited teams, composed of about 1500 academics in four universities in Morocco, were analyzed using a cross-matrix of members' co-publications, an intra-collaboration index, Lorenz curve of both internal co-publications and sole-publications, with respect to team's size. Our findings show that internal co-publications and sole ones are higher for small size teams and that the Lorenz distributions of these two indicators are unequal in favor of small size teams. We discuss the implications of our findings for science policy, beyond size, such as the output- instead of input-based perspective to form a team, time requirement to build a collaborative team, inter- and intra-disciplinary oriented research, team directorship, etc.

Keywords Collaboration · Science policy · Science team · Research unit · Co-publication · Co-authoring

Introduction

Scientific collaboration represents the major social component of modern science (Glänzel and Schubert, 2005; Wuchty et al., 2007; Milojevic, 2010). Thus, science teams are built to perform collaborative science on either micro (individual), meso (research unit, institution, etc.), or macro scale (national, international, field, etc.). Besides addressing research performance at a micro-level as well as at a macro one, a number of researchers studied

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science teams at the meso-level as the first 'cell' for scientific collaboration. Among them we point out those by Newman (2004), Carayol and Matt (2004), Pepe and Rodriguez (2010), Bellanca (2009), De Stefano et al. (2011), Horta and Lacy (2011), Birnholtz et al. (2013), Brandt and Schubert (2013), Cook et al. (2015), and Sandstrom and Van den Besselaar (2019).

However, all these works on science teams at meso (intra-institutional) level examined the effect of the team size on their output (papers) and or its productivity, without distinguishing between their internal co-publications and/or sole ones. We mean by internal co-publication any publication co-authored by at least two members of the same science team (an internal co-publication may be co-authored by other authors from outside this team). A sole publication refers to any publication authored by a member alone without any other member of his/her science team (a sole publication may be co-authored by other authors from outside the team).

Analysis at this lowest level of granularity is expected to bring responses to recent collaboration dynamics where inter-institutional and international collaborations are increasing while intra-institutional collaboration is decreasing (Chinchilla-Rodríguez et al., 2021).

Focusing distinctively on internal co-publications and sole ones at the university team level is the first contribution of this paper, introducing in this regard a new quantitative method based on a dedicated cross-matrix shaping internal co-authorship upon which we build the intra-collaboration indicator.

The second contribution of the paper is that it addresses intra-collaboration at university team's level within the context of a developing country. Other studies in this context are those by Kannebley et al. (2018) which investigated the scientific production of coordinators of Brazilian research laboratories and by Aparecido et Kannebley (2019) investigating the scientific production and patenting of Brazilian laboratories. All the others works were conducted in developed country contexts (Bonaccorsi et al. (2006) in an Italian context, Carayol and Matt (2004) and Carayol and Matt (2006) in a French context, Cook et al. (2015) in a UK context, Sandstrom and Van den Besselaar (2019) in a European context, Brandt and Schubert (2013) in a German context, Verbree et al. (2015) in a Dutch context, De Saá-Pérez et al. (2015) in a Spanish context.

Thus, 120 accredited science teams composed of about 1,500 academics in four Moroccan universities are analyzed. For each academic, published papers included in the Web of Science database are retrieved and ordered in a specific matrix to analyze both internal co-publications and sole publications.

The contrapositive of the conditional statement is adopted to disprove the science policy logic behind the structuration of research landscape at university: if the team size increases then the outputs increase too. This paper is an extended and revised version of the ISSI2021 Conference paper (Achachi & Bouabid, 2021).

Literature review

The analysis of scientific collaboration allows putting forward patterns, organizing modes, obstacles and opportunities for highly productive and impactful research. Scientific collaboration represents the major social component of modern science (Glänzel and Schubert,

2005; Wuchty et al., 2007; Milojevic, 2010). It can be observed on several levels: micro (individual), meso (research unit, institution, etc.), and macro (national, international, field, etc.). Since the earliest collaborative paper by Hooke Oldenburg, Cassini, and Boyle in 1665 (see Beaver & Rosen, 1978), the collaborative process of science has undergone a significant evolution both locally (Jones et al., 2008) and worldwide (Larivière et al., 2014; Wuchty et al, 2007). Yet, science of team science (SciTS) has recently risen to advance deep understanding of the complexity of scientific collaboration and the value of team science (Hall et al., 2018) and use science to transform the ways researchers perform science to enhance their effectiveness (Liu et al., 2020).

The complexity of team collaboration requires adopting appropriate tools to evaluate targeted collaboration's facets. As pointed out by Glänzel and Schubert (2005) and Melin and Persson (1996), co-authorship is a particular outcome of collaboration. It can be used as a proxy to study collaboration, despite some criticisms raised for example by Katz and Martin (1997) or Laudel (2002). Indeed, Katz and Martin (1997) raised the fundamental question linked to what may then considered as intra- or inter-collaboration, on which relies co-authorship counts. They also warned about the necessity to distinguish between collaboration and co-authorship, evoking on one hand the fact that researchers may work closely together but may not publish or decide to publish their results separately, called later *collaborative team* by Wang and Hicks (2015), and on the other hand, the fact that researchers who have not worked together in their research, may nevertheless decide to pool their findings under the form of a common paper, called later *coauthor team* by Wang and Hicks (2015). Laudel (2002), when attempting to measure to which extent co-authorship reflects collaboration, underlined that co-authorship is just one of three forms to reward a collaboration: a co-authorship, an acknowledgement or nothing at all, and stated that about half of the collaborations were not rewarded at all, neither by co-authorship nor by an acknowledgement.

Despite these criticisms, co-authorship remains a major proxy to study scientific collaboration. According to Toivanen and Ponomariov (2011), the collaboration caught through co-authorship has become a standard. They found that while pragmatic factors and personal motives are major reasons for collaboration at a micro-level, increasing cost, complexity of instrumentation, interdisciplinarity, policy and market driven demands of science are the main reasons for collaboration at a macro-level. Persson et al. (2004), Wuchty et al. (2007) and Larivière et al. (2014), all found that co-publications were more frequently cited than sole publications. Furthermore, these co-publications have a positive impact on scientific productivity at the individual, institutional, and national levels, as well as on socioeconomic partnerships (Helga et al., 2009; Lebeau et al., 2008). This strong correlation has been demonstrated in several other studies within different contexts (Lee & Bozeman, 2005, Haslam et al, 2008, Defazio et al, 2009, Abramo et al., 2011, Bouabid, 2014).

In the rich literature on scientific collaboration, the majority of studies were particularly oriented towards inter-institutional, international, and national collaborations or in specific scientific disciplines (Kumar, 2015; Savic et al., 2015; Wuchty et al., 2007; Jones et al., 2008). Intra-institutional collaboration has also caught academic attention. In a comprehensive literature review by Kumar (2015), he mentioned two studies conducted by Newman (2004) and by Pepe and Rodriguez (2010). Bellanca (2009), De Stefano et al. (2011) and Birnholtz et al. (2013) analyzed intra-institutional collaboration of respectively the University of York (UK), University of Salerno (Italy), and two campuses of Cornell University
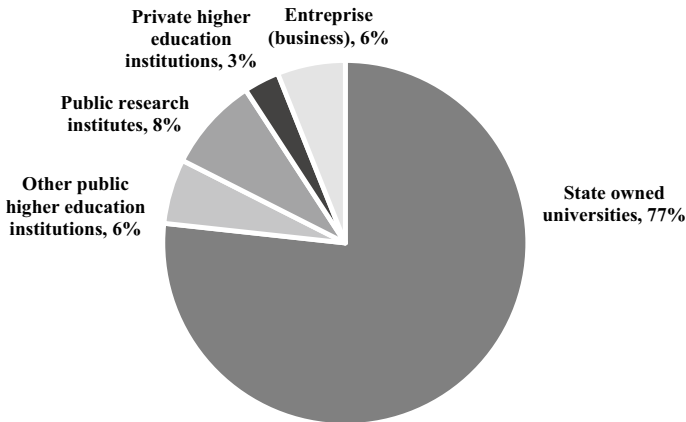
Fig. 1 Number of researchers Breakdown according to research performers in Morocco

(USA). Jones et al. (2008) examined the multi-university research teams' between-institution and within-institution outputs and impact. Considering the topic composition of teams, Smith et al. (2021) studied the relationship between topic overlap and the probability of collaboration at a U.S. university.

Addressing research performance at a the meso-level considers the science team as the first 'cell' for scientific collaboration. This team is put forward for its role as a site of idea emergence, knowledge creation, diffusion and discovery (Bonaccorsi and Daraio, 2006; Carayol & Matt, 2004; Von Tunzelmann et al., 2003; Horta & Lacy, 2011).

However, all these works at a meso level examined the effect of the team size on the team's whole output (papers) and or its productivity, without distinguishing between their internal co-publications and sole ones. This partition is crucial because being formally organized together in a team, members are supposed to interact and exchange scientific information in order to foster their collaborative outputs. Indeed, as advocated by Sandstrom and Van den Besselaar (2019), the performance—productivity and impact—of a group relays on its capacity to combine and use different competencies in a creative way. In their analysis of the performance of teams, Von Tunzelmann et al. (2003) stated that research and knowledge productions thrive on cross-communication and inter-linkages. Furthermore, and as a policy implication, this partition will contribute to bring responses to patterns shaping collaboration dynamics. Chinchilla-Rodríguez et al. (2021) demonstrated that over three periods, 2008–2011, 2011–2014, and 2014–2017, inter-institutional and international collaborations have been increasing while the single institution including intra-collaboration has been decreasing.

The first contribution of this paper is that it focuses distinctively on internal co-publications and sole ones at the university' team level, through a proposed quantitative method based on a dedicated cross-matrix shaping internal co-authorship upon which we build the intra-collaboration index. The second contribution is that the paper addresses intra-collaboration at a team's level in a developing country, a context which research has rarely dealt with.

Overview of the Moroccan research performers

In Morocco, several institutions perform research activity. The main ones are universities (state owned universities) in terms of number of researchers (Fig. 1) and outputs such as publications. There are currently 12 state-owned universities located in major cities in the country.[1]

For higher performance and greater visibility of university research, the Ministry of Scientific Research launched a policy in 2006 to reorganize the research landscape, aiming at reaching critical team's size for efficient research investment and research performance. In this process of structuration, universities have adopted a common national platform that set criteria for organizational science teams:

- Type 1: *Equipe*, composed of 3 academics;
- Type 2: *Laboratoire*, composed of at least 6 academics;
- Type 3: *Centre*, which is a group composed of both types 1 and 2.

In an international context (mostly developed countries), the National Academy of Sciences—National Research Council of the USA (2015) refers to a science team as (pg. 2):

Most team science is conducted by 2 to 10 individuals, and we refer to entities of this size as science teams.

This policy has allowed the transition to a more formal system where teams are compulsory accredited by the University Council, based on pre-defined eligibility criteria. The accreditation criteria are mainly scientific outputs, such as published papers, patents, and PhD dissertations, R&D contracts with companies, cooperation projects and funds. Accreditation of teams relies mostly on external peer-review evaluation conducted on a four-year period basis. The main lever of this science policy remained increasing the number of academics in a team, expecting to reach critical size for higher outputs. This policy has sought teams under an input-based perspective, which means that building teams relies on existing administrative arrangements, where all the scientists of a team, whether or not they publish, constitute its population (Rey-Rocha et al., 2006). At the opposite, there exists worldwide another approach adopting the perspective of an output-based team, where teams are built mainly on the basis of co-authorship frequencies, and cross citations (Rey-Rocha et al., 2006).

Data and methods

This research analyzes the teams' intra-collaboration of academics, after a four-year period following their accreditation cycle for the period 2008–2011, that is 2011–2014. It covers the Faculties of Sciences (*FS*) performing research in the fields of science, technology engineering and mathematics (STEM) within four Moroccan universities[2]: Mohammed V University (*UMV*), Ibn Tofail University (*UIT*), Mohammed First University (*UMP*),

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[1] Data from the Hassan II Academy of Science and Technology. The total number of researches is 54.087, as of the year 2016 available data.

[2] The three main criteria for this choice among other universities were age, size and geographical location.

Moulay Ismail University (*UMI*). The selection of these institutions is based on three criteria: age, size and geographical location.

The publications being studied here were retrieved from the WoS Core Collection database over the period 2011–2014.

The present research focuses on teams of the second type as science team and teams of the first type with more than or aqual to 6 academics, since this first type with an average of only 3 academics, in all institutions under study, is not large enough to allow an objective analysis of intra-collaboration. *From now on, we refer to the studied science teams as teams*. Our sample includes 120 teams out of a total of 175 in these four universities, and 1500 academics out of a total of 1680 in the same universities in the field of science, technology, engineering and mathematics (see Table 2). In terms of disciplines, the fields of physics and environmental sciences were the most represented (Fig. 2). It is worth informing that all teams are mainly disciplinary-focused, with an organization more linked to teaching departments at the university, except for the environmental sciences which fall most of the time either under biology or under chemistry (Table 1).

After identifying the accredited teams, we proceeded to retrieve the full name of each academic in these teams. Then, we ordered them in a matrix, which we call "intra-collaboration matrix"$[C_{ij}]$, as shown in Fig. 3. For example, for a team with *n* academics, the intra-collaboration matrix is built by placing the academics' names in rows, from bottom to top, numbered from *1* to *n,* then cross-referencing them by placing the academics' names this time in columns from left to right, starting by the *nth* academic to number *1*. The matrix allows cross-referencing all academics to plot their internal co-authored papers. Sole papers are placed on the diagonal. The intra-collaboration $[C_{ij}]$ matrix is symmetrical.

To read the matrix in Fig. 3, as an example, the academic *2* has 4 co-authored publications with academic *n* and 2 with academic *j*, and 5 publications alone without any co-authorship within his/her team members (besides his/her 6 internal co-publications).

In this matrix, gray cells represent the number of co-publications within the same team while the diagonal cells contain sole publications. A sole publication refers to a publication made by an academic without any co-authoring with his/her team members. It may be either a single authored or a co-authored publication with a third party outside the team. Mathematically setting:

$$C_{ij} = \begin{cases} number\ of\ \text{in}ternal\ co-publications\ if\ i>j \\ number\ of\ sole-publications\ if\ i=j \end{cases} \text{with } 1 \leq i,j \leq n$$

This analysis uses all types of publication, i. e. articles, proceedings papers, letters, editorial materials, reviews, books, book chapters, etc., retrieved from the Web of Science Core Collection database (Clarivate Analytics) over a four-year period after the accreditation cycle period of 2008–2011, that is 2011–2014. This four-year timespan ensures the elimination of yearly fluctuations in the publishing process. The data was retrieved in a format with all the fields of the database records, namely: authors, titles, journals, addresses, etc. After refining the raw data, the corpus contains more than 1,460 publications.

Our method is the contrapositive of the conditional statement. Since, the science policy behind the structuration of research landscape at university was mainly driven by the logic that *if the team size increases then the outputs increase too*, we will explore the situation when the outputs (either internal co-publications and sole publications) are lower and seek whether the team size is lower too.

Table 1 Descriptive data of Morocco

	Population (million)	GDP per capita (US$)	GERD% GDP	Researchers % million population	Scientific publications**	Publications per million population
Morocco	36.59	3222 (2018)	0.75 (2016)*	1073 (2016)	5917 (2018)	1.64
World	7591.93	11,374 (2018)	2.27 (2018)	1410 (2015)	3071,917 (2018)	4.04

The year between parentheses refers to the available year. Source: World Bank (retrieved October 19th 2020)

* Source: Academy Hassan II for Science and Technology (http://www.academie.hassan2.sciences.ma/pdf/rapport_sur_la_recherche_2019.pdf)

** Source Web of Science Core Collection (Clarivate Analytics)

Table 2 Number of teams, academics and PhD fellows in the 4 universities under this study, and in all universities with their evolution over a decade from 2009 (base line) and 2018. Values in parentheses indicate the share of the 4 universities out of all universities

		2009 (base line)	2018	Change (18/09)
Teams: all universities	type 1	445	326	− 27 (%)
	type 2	488	690	41 (%)
	Type 3	20	51	155 (%)
	Other	29	0	
	Total	982	1067	9 (%)
Teams: sample (4 universities)	type 1	116 (26%)	120 (37%)	3 (%)
	type 2	175 (36%)	156 (23%)	−11(%)
	Type 3	0 (0%)	25 (49%)	
	type 1	8 (28%)	0	
	Total	299 (30%)	301 (28%)	1 (%)
Academics: all universities	STEM	5037	6628	32 (%)
	MED	1216	1532	26 (%)
	SSH	3850	5794	50 (%)
	Total	10,103	13,954	38 (%)
Academics: Sample (4 universities)	STEM	1680 (33%)	2479 (37%)	48 (%)
	MED	21 (2%)	714 (47%)	3,300 (%)
	SSH	1020 (26%)	1647 (28%)	61 (%)
	Total	2721 (27%)	4840 (35%)	78 (%)
PhDs fellows: all universities	STEM	6970	14,352	106 (%)
	MED	1599	3084	93 (%)
	SSH	10,279	16,877	64 (%)
	Total	18,848	34,313	82 (%)
PhDs fellows: Sample (4 universities)	STEM	3084 (44%)	5195 (36%)	68 (%)
	MED	0 (0%)	1206 (39%)	
	SSH	4159 (40%)	6199 (37%)	49 (%)
	Total	7243 (38%)	12,600 (37%)	74 (%)

STEM: Science, Technology, Engineering and Mathematics, MED: Medical sciences, SSH: Social Science and Humanities

Results and discussion

The typology of the teams

To quantify the team size, we suggest the grouping index that refers to the average number of academics in a team within a scientific field or an institution. This index is calculated for each institution and for each field. It is defined as the sum of the numbers of academics per team for all teams, divided by the number of teams in a given institution or field:
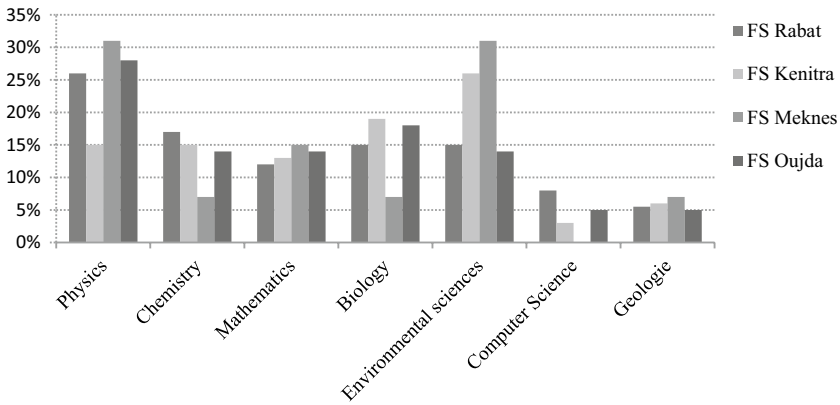
$$I_g = \frac{\sum_{i=1}^{m} n_i}{m}$$

Fig. 2 Distribution of accredited teams according to scientific fields in the four institutions

Fig. 3 Example of intra-collaboration matrix $[C_{ij}]$ for a team of n academics

where m: number of teams in the institution or field and n_i: number of academics in team i.

The grouping index's values are reported in Table 3. It shows that the largest teams occurred at the Faculty of Meknes with more than 14 academics per team. Small team size is found at the faculty of Rabat (an average of 9.9), knowing that the threshold required for constituting an accredited team is nine academics. Moreover, at the Faculty

Table 3 Values of the grouping index (I_g) of academics in teams by institution and field

| | FS oujda | | | FS rabat | | | FS kenitra | | | FS meknes | | | Average |
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Field
Physics	8	11.3	14	6	7.7	12	6	7.2	9	12	11.5	18	9.1
mathematics and computer Science	10	11.3	13	9	11.0	14	7	9.4	13	16	20.5	25	11.7
Geology	–	15	–	6	12.0	20	6	7.5	9	–	6.0	–	10
Chemistry	12	13.7	16	6	11.3	16	6	5.6	12	–	17.0	–	10.3
Biology and environmental Sciences	10	13.0	17	6	10.0	21	6	9.9	15	9	14.6	20	11.2
Average		12.4			9.9			8.5			14.1		

Bold numbers are the average values of the index
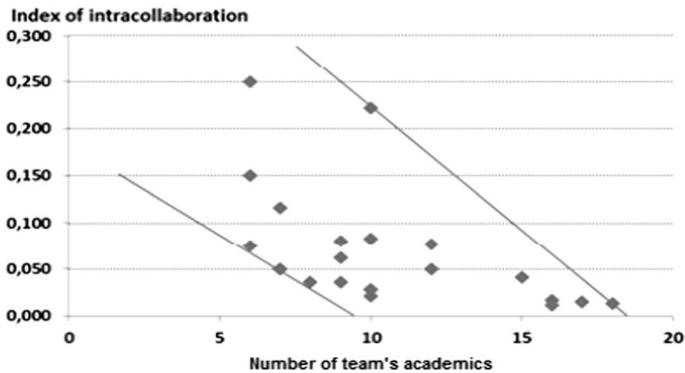
Fig. 4 The intra-collaboration index with respect to team's size (number of academics)

of Rabat, there is a significant gap between the minimum and the maximum values of the grouping index *Ig* among fields.

It can be noted that in the field of physics, academics are the least grouped ones, with an Index of about 9. On the contrary, mathematics and computer science is the field where academics tend to gather more in a team, irrespectively of the institution (almost 12 academics per team).

Intra-collaboration metrics

To explore the intra-collaboration outputs, we consider three metrics: (i) the intra-collaboration index, (ii) the number of cells with co-publications (cells in gray color in Fig. 3) and finally, (iii) the cumulative number of co-publications within these cells. The first metric is built for the analysis purpose, while the Lorenz curve is used to depict all three metrics.
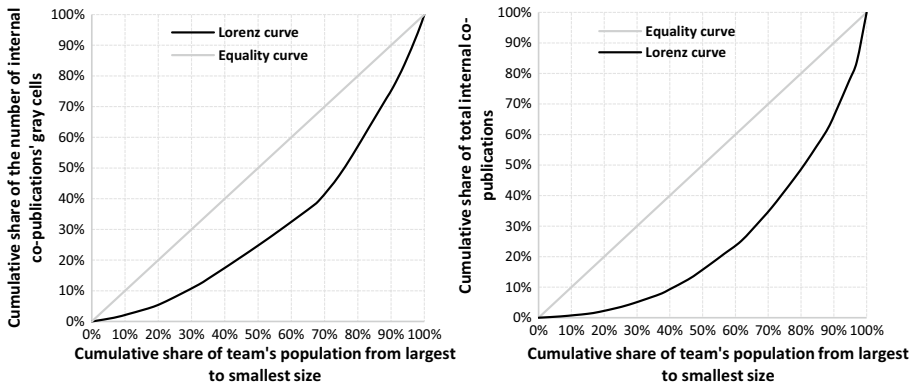
Intra-collaboration index

The index of intra-collaboration is defined as the number of cells where there are intra co-publications (cells in gray color in Fig. 3) divided by the number of cells in the lower (or upper) part of the matrix (without the diagonal). We only consider the lower part of the matrix as the co-publications matrix is symmetrical. In a mathematical form, we write this index as follows for the team *i*:

$$I_i = \frac{c_i}{(n_i(n_i - 1))/2}$$

where c_i is the number of cells with co-publications and n_i the number of academics in team *i*.

This size-normalized index ranges from *0* when there is no co-publication between the team' academics, i.e. '*loneliness*', as expressed by Von Tunzelmann et al. (2003) and *1* when all cells are in gray color, meaning that all academics have co-publications among them, i.e. full collaboration.
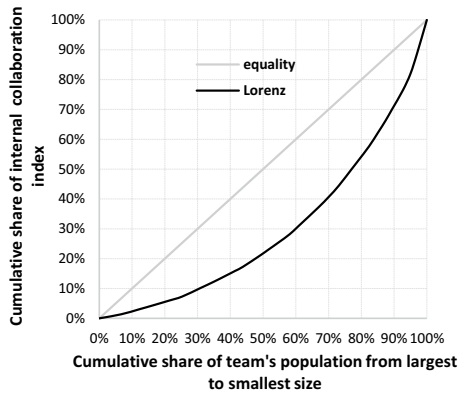
Fig. 5 Distribution of internal co-publications with team size (number of academics)

Figure 4 shows the intra-collaboration index according to size for all studied teams. The two lines band the scatterpoints. The intra-collaboration index is low (less than 0.25) and decreases when the size increases. After some years, the research structuration process of grouping more academics is not yet reaching high levels of team's co-authorship outputs.

The reason behind this low co-authorship is that achieving this goal needs teams to go through several stages in their life, during which compatibility and interconnection, besides incentive and infrastructure, are established as key factors of collaboration (Hara et al., 2003). Some studies described four consecutive stages of team development: forming, storming, norming, and performing (Bennett & Gadlin, 2012). These stages require enough time while the process of structuration is recent. Time is also required to support strong individual relationships, which are found to allow the establishment of trust and contribute to a better transfer of information and ideas between academics (Jha & Welch, 2010). Horta and Lacy (2011) supported the idea that greater intensity of communication between individuals and groups is a key factor for fostering creativeness and research results. Hall et al. (2018), in their review on science of team science, reported literature underlying three vectors in effective team: Cognitive, Motivational & Affective, and Behavioral. Moreover, according to the survey conducted by Achachi et al. (2016), the majority of researchers stated that affinity is a fundamental vector to promote collaboration between them. This demonstrates that intra-collaboration does not immediately increase with team size, but rather increases gradually with other factors such as relationship, work methodology, writing style and interconnection at work, shared goals, incentives, etc. All these factors need much more time to be established and require a decade or even more. Liu et al. (2020) said that a team is not a '*loosely aggregated bunch of persons*'.

In many Moroccan university teams, regular conferences and seminars are quite rare, and board meetings are simply impromptu. There are no compulsory or formal rules to follow in order to maintain team' members regular interactivity, communication and commitment to a *team's scientific life*. Several studies underline the importance of face-to-face (FTF) communication for successful teams (Jeong & Choi, 2015), particularly at the institutional level (Smith et al., 2016).

Fig. 6 Distribution of intra-collaboration Index with team size (number of academics)

Internal co-publications and sole publications

To better understand the evolution of the intra-collaboration according to team size, the Lorenz curve is used to depict inequality of the internal co-publications according to team size. Figure 5 shows this relationship for all teams by setting a threshold of three gray cells in the collaboration matrix. Both curves, of the number of gray cells and the total number of internal co-publications, illustrate clearly the inequality in the distribution of internal co-publications according to the team size. The inequality is higher for total internal co-publications than for gray cells (comparing curves in the two figures). For total internal co-publications, for instance, 40% of the population in large-size teams on average holds only 10% of the internal co-publications (figure on the right). Nevertheless, 20% of the academics—all in small-size teams—holds 50% of these papers (figure on the right).

This finding corroborates previous empirical observations that size does not matter much for a team's performance (Von Tunzelmann, 2003). It may even have a negative effect on productivity, regardless of the context: Qurashi (1991) in an Indian context, Seglen and Aksnes (2000) in a Norwegian context, Carayol and Matt (2004, 2006) in a French context, Bonaccorsi et al. (2006) in an Italian context, Cook et al. (2015) in a UK context, Sandstrom and Van den Besselaar (2019) in a European context. In the French context, which is to a large extent the transposed model in Morocco,[3] Carayol and Matt (2006) explained this relation in favor of small-size teams by lower coordination costs, more streamlined decision-making processes and smaller volume of administrative duties.

In a better case, productivity evolves in an inverted-U curve with size, up to an optimal size—between 5 and 9 members—then decreases again (Qurashi, 1991; Von Tunzelman et al., 2003; Verbree et al., 2015; De Saá-Pérez et al., 2015). In the context of a developing country, Aparecido and Kannebly (2019) also found that medium-scale university teams were the most scientifically productive in Brazil (about 17–20 members in total including all categories). In the best case, the production continue to increase with size but less proportionately (see for example references reported by Hall et al., 2018).

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[3] It is resulting from one side the colonial heritage, as Morocco were under French rule 1912–1956 an the other side the intensive cooperation ties. See Achachi et al.).

Activeness of small teams goes beyond outputs such as publications. Some research works reported that small teams are more likely to generate new disruptive science and technology, i. e. coming up with new ideas and opportunities, whereas large teams are more likely to develop existing ideas (as reported both by Hall et al., 2018; Liu et al., 2020).

Some may say that these results are expected since from an individual's point of view, the likelihood of collaborating within a small team is higher than when that same individual is put in a large team. We plot in Fig. 6 the intra-collaboration index that normalizes the cumulative internal co-publications to the size of the team, which avoid any bias when representing the cumulative number of internal co-publications. The result is similar to that of the cumulative share of internal co-publications, that is, an inequality in the distribution of internal co-publications index according to size.

With respect to fields, the results show some differences among the five broad scientific fields (see appendix). Our results show that more equal production happens in the fields of Mathematics & Computer Science as well as Physics (see appendix). Less equal production happens in fields relying more on organized-team work, hard-science infrastructure and intensive-lab equipment, such as biology, geosciences and, to a lesser extent, chemistry. Laudel (2002) asserted that co-authorship is substantially governed by *informal rules* and *habitualised practices*, depending on each field.

The observed low internal co-publication in all fields may be because teams are built on a field specialization basis with mainly disciplinary focus (strong overlap). Indeed, all teams under study were devoted to a specific scientific field, where team members had very similar specialization, called vertical specialization. While this scheme of team organization seems to favor collaborative work among its members in some contexts (Laudel, 2002), it is found to disfavor the scientific production in other contexts of a developed country (Carayol & Matt, 2004; Smith et al, 2021) and a developing country (Brazil) where Aparecido and Kannebly (2019) found that specialization does not seem to be beneficial for either scientific production or patenting. In the Moroccan context, this specialization within the team's organization is likely supporting competitive attitude among them, as they are working on the same—or almost the same—research topics, enhanced by career promotion requirements. Smith et al. (2021) found that scientists and teams tend to seek collaborators whose expertise is outside, but not far, of the topical range spanned by their own research. They added that the medium-to-high degrees of topic interest' overlap create niches in which researchers are more inclined to competition rather than collaboration and that very low degree of topic interest is likely to complicate communication and agreement between team' members. In consonance with these findings, Dinges et al. (2021) concluded that interdisciplinarity is typically a result of very closely related sub-disciplines. Indeed, when studying excellence, interdisciplinarity and collaboration in research networks in Austria, they found that over three periods, 2004–2007, 2008–2012, and 2013–2017, the interdisciplinarity scores are around 2–2.5 on a scale of 0 as a minimum reflecting low inter-dsciplinarity (full overlap) to 5 as a strong interdisciplinarity.

Perhaps, horizontal specialization, i.e. intra- or inter-disciplinary research activities, may be suitable for teams to perform better. Indeed, Schubert (2014) put forward that "even if a certain specialization strategy is optimal, it may not be optimal for the research group". Horizontal specialization should be carefully implemented in order to: (i) favor more intra-disciplinary ties linked to highest probability of co-authorship than interdisciplinary ones (Dinges et al., 2021; Smith et al., 2021) and (ii) avoid 'problematic' situation and results, associated with interdisciplinary research (Walsh et al., 2019).

Increasing team size has not resulted in increasing internal co-publications. This raises a question about how sole publications evolve with size. In fact, while it is found that forming

Fig. 7 Distribution of cumulative number of sole publications as a function of the team's size (number of academics)
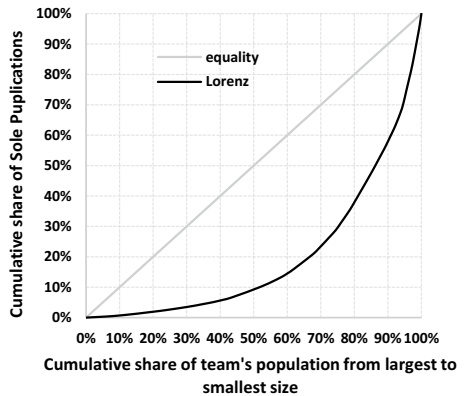
Table 4 Internal co-publications and sole publications of teams directors (PI)

	Sole publications	Internal co-publications
PIs publications in number	3	25
PIs publications as % of team's total	0.4%	3.4%

larger teams results in lesser internal co-publications, it may be expected that grouping will result in greater sole publications. That is why the Lorenz curve is drawn similarly for the distribution of the cumulative sole publications with team's size (Fig. 7). It is noticed that the distribution of the team's outputs on a sole basis is unequal with team size. On average, 50% of the population—all in large-size teams- holds just 10% of the cumulative sole publications, while 20% of the population—all in small size teams holds 60% of these sole publications.

Despite the academics grouping policy implemented in universities since 2006, neither internal co-publications nor sole ones are found to increase with team size. The main obstacles towards teams performance are lack of funding and teamwork' culture. Both team work and affinity are crucial for team performance. Wang and Hicks (2015) advocated that collaborative team are self-assembled and fluid, since the idea generation precedes or co-evolves with the intra-process of team assembly.

Consequently, academics are likely to prefer other forms of collaboration, particularly international collaboration that brings funding and recognition. International collaboration is often built on individual initiatives rather than institutional policy or agreements (Bouabid, 2017, in developing country; Bordons et al., 2013, in developed country). When studying dynamics in collaboration strategies/patterns at the global level (developed and developing countries), Chinchilla-Rodríguez et al. (2021) supported that science policy should care about local researchers since these dynamics are built by the self-interests of individual scientists rather than other institutional or political factors. Likewise, Waast (2010) and Achachi et al. (2016) stated in the case of developing countries that international collaboration is sought to keep the scientific level of researchers up-to-date, reward scientific recognition, and provide financial support. Indeed, Chinchilla-Rodríguez et al.

(2021) evidenced that internationally collaborative publications are negatively and significantly correlated with national financial support (in terms of R&D expenditures), in other words, international collaboration is a life-saver for investigations in the event of locally financial shortage.

Furthermore, team's outputs are found to be positively correlated to PI (Principal Investigator) activeness (Cook et al., 2015). However, we have noticed in the Moroccan context a number of team directors (PI equivalent), of the 120 teams under study, being inactive in terms of either internal co-publications or sole ones. Table 4 shows that just 3.4% of the total internal co-publications is co-authored by the PIs while they gained only 0.4% of sole publications out of the total of all teams. With respect to definitions above, the 'group' by Cook et al. (2015) is similar to team as in our research since the groups they studied were, on one hand located in departments within universities and on the other hand their mean size was 7.3, with a maximum of 31 members including on average 3.0 PhD fellows.

The lower productivity of the PIs could also be related to the vertical specialization of the studied teams. Indeed, in a similar context, the Brazilian one, Kannebley et al. (2018) highlighted a positive productivity differential in favor of the PIs (coordinators) of multi-activity laboratories than in more restricted scope of activities. But, they argued that this prevalence may be due to the organizational production form of these teams, in which the PI has control over the scientific production of his/her laboratory and the importance of the research carried out in the post-graduate system.

Two other factors appear as shortcomings to the internal and sole team's publishing: (i) the lack of other human resources than academics and (ii) the teaching overload. With regard to the first shortcoming, postdoctoral positions do not exist at Moroccan universities (not permitted by law), while this category of research personnel plays a key role in the team outputs (Carayol & Matt, 2006). Horta and Lacy (2011) concluded that teams' output is positively impacted by its organization when including both academics, postdoctoral and doctoral fellows; instead the output is negatively impacted when limited to academics and doctoral fellows only. At Moroccan university, academics are all full Professors, under three categories: Professor of the Higher Education, Professor Habilitated for research (Associate Professor) and Assistant Professor. All are required to perform both research and teaching activities. The latter is not permitted to supervise PhD students and research thesis.

The second shortcoming, i. e teaching duty, is found to reduce scientific outputs of academics. Teams are typically multi-functional: engaged in teaching and research activities. Horta et Lacy (2011) advocated that academics should be relieved from exclusively teaching undergraduates, since it negatively impacts their productivity. In Moroccan university, teaching duty is beyond rationality. Indeed, with a ratio of students to teaching staff of an average of 54.5 in 2017, it is far behind those of developed countries such as (in the same year): France (16.1), Germany (11.7), Italy (20.9), Netherlands (14.6), Portugal (14.7), Spain (11.7), USA (15.3). Horta et al. (2012) found that teaching no undergraduate students is slightly positively affecting productivity.

Conclusion

Science policy for structuration of the research landscape at universities in Morocco was mainly driven by the logic that if the science team' size increases then its outputs increase too. Adopting the contrapositive of this conditional statement, we find that when the outputs (either internal co-publications and sole publications) are lower, the team' size is larger, instead of being smaller. Thus, we conclude that in the Moroccan context, the science policy towards grouping more academics into science teams hasn't yet resulted in higher scientific outputs. This finding is in line with other studies in the context of developed countries.

The policy aiming at increasing science teams' size does not seem yet to stimulate shared work resulting in a *collaborative team* and co-publications performance. This policy is likely in its early stages to build real science teams, marked by favoring information exchange and communication between its members, but not yet at the upward stage of team work and synergy prior to the stage of performing collaborative science.

Thus, the results and findings of the work should be considered with respect to the period of study (2011–2014) as the time to implement the policy which is recent (2006) and to anchor the structuration at universities is rather longer. Similar analysis with more recent period is then sought as a perspective of this work.
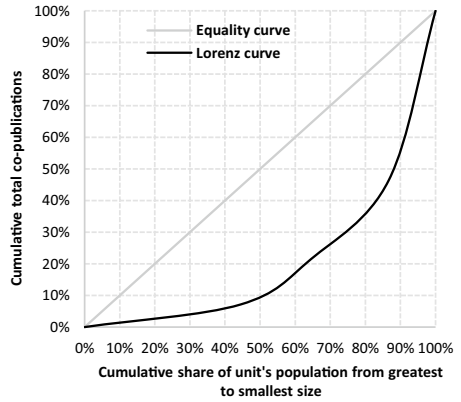
Since this policy is recent, the 'culture' of affinity, interconnection and relationship, intra-disciplinarity, teams directors (PIs) activeness, and teaching load, should be put forward as key factors alongside with the size, to let the science team perform better. These prerequisites are to be considered to reach an optimal team size rather than extending it ad infinitum. The prior prerequisite may be the approach itself behind the institutional research structuration. In the adopted science policy, teams are built from an input-based perspective, while the approach promoting an output-based team perspective could be explored, or even a hybrid one.

Exploring these prerequisites, rather than team size alone, may significantly contribute to overcoming the obstacles encountered by science teams, which brings researchers to focus on international collaboration instead of local and close collaboration. Science policy towards universities should be clear when it comes to research versus educational orientation, which fundamentally governs the formal organizational science team and its performance. Furthermore, this policy ought to rethink scientific collaboration in the light of: (i) recent dynamics of collaboration at the three levels (intra-institutional, inter-institutional, international collaboration), and (ii) the disruptive event by the Covid-19 pandemic, leading undoubtedly to alter these forms of collaboration.
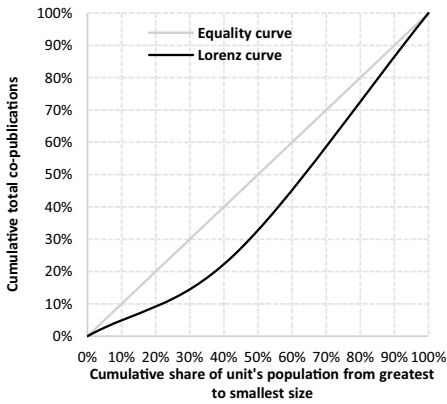
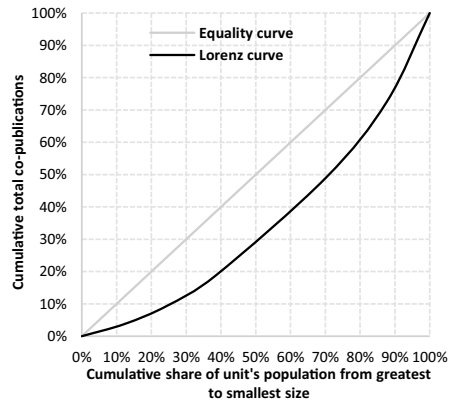## Appendix: Lorenz curve of internal co-publications with respect to team's size for the five broad scientific fields
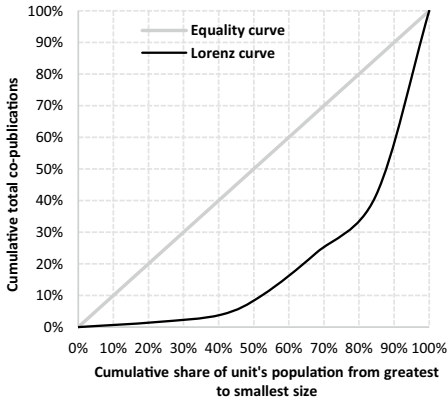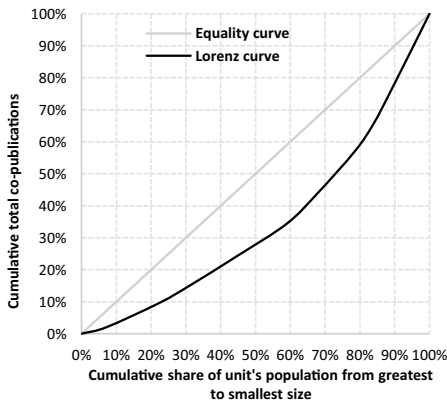

Biology and environmental sciences

Geology

Mathematics and computer Science

Physics

Chemistry

Declarations

Conflict of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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