Peer-making: the interconnections between PhD Thesis Committee membership and co-publishing

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Abstract: the article relies on the analysis of Social Networks in order to compare the networks at work in the composition of thesis committees between 2003 and 2008 in a French provincial university in three very different disciplines –astrophysics, archaeology and economics– so as to test the hypothesis that connections actually pre-existed to graduation. Were members co-authors of scientific publications or were committees constituted only for the sake of awarding a PhD? Astrophysics and its "equipment" ethos is the one to superimpose most often committee membership and co-publishing. Archaeology falls somewhere in-between, due to the greatest scarcity of committee members. Last of the three, economics actually separates the two types of collaboration by most frequently inviting international researchers.

Key Words: PhD, Networks, PhD Committee, Astrophysics, Archeology, Economy

[1] Marie-Pierre Bès passed away while your manuscript was under review.

1 Introduction

Entering the field of science implies meeting a series of demands meant to test the graduate's capacity to propose original scientific approaches, but also to comply with the requirements generally set and agreed to by the research community (Nettles & Millett, 2006). While, thesis committees (*i.e.* the examining committee acting at the thesis defence) a priori are transitory communities set up only for the sake of awarding a doctorate, the guiding hypothesis of this article is that they are shaped by some previous social density. Supervisors must embody disciplinary expectations, compliance with scientific ethos, norms validating the required work and capacity for a critical evaluation of results. The group of peers thereby selected must assess the work presented, but must also stand for the broader research community working in the field the graduate will join.

There have been few studies so far to understand the complex processes at work in setting up thesis committees, to grasp the dynamics of scientific validation as well as the different types of relationships developed between and with committee members. Some studies have focused on the gender-based or linguistic distribution (Breimer & Nilson, 2010; Breimer & Leksell, 2011; Pezzoni *et al.*, 2016) of PhD students when graduating. Others have underlined the influence of first publications on careers (Breimer & Nilson, 2014; Fonseca *et al.*, 1998) without precisely measuring the concrete impact of the supervisors' and committee members' support (Erhenberg *et al.*, 2010: 212). We suggest a novel approach: focussing on committee members co-publishing practices and, on the side, on whether and to what extent PhD students are included in these research communities.

Our hypothesis is that setting up a thesis committee may well be an opportunity for reinforcing previous collaborations, actually evidenced by joint publications. Simultaneously, PhD graduation, which signals PhD students' entrance into the field of science, may be doubled up by a joint publication with one of the committee members. PhD students' contribution to scientific production is consistent (Larivière, 2012; Watts, 2012), and helps reinforce her/his recognition as a fully-fledged member of the research community (Donner, 2020).

In this article, we use social network analysis (SNA) to reveal the various types of thesis validation communities. This methodological and heuristic choice relies on a great number of research works carried out in sociology of science (Kretschmer, 1994; Katz & Martin, 1997; Newman, 2001; Newman, 2004; Moody, 2004).

Our investigation focusses on the formation of PhD thesis committees in three research laboratories from 2003 to 2008 in the city of Toulouse, France. The choice of this specific period allows us to grasp the way thesis committees were formed before the significant institutional changes, which affected the French university system in 2009: generalised trend to shorten thesis duration (including in social sciences), parity standards in the constitution of juries, gradual disappearance of unfunded theses. We compare the actual publishing practices of PhD students and of their committee members in three different disciplines (i.e. astrophysics, economics, and archaeology).

In order to grasp the disciplinary specificities observed and to shed light on certain internal differences within the research laboratories under consideration, we complement the social

network analysis of jury composition and co-authorship networks with qualitative material. A wave of 10 interviews carried out with PhD thesis directors makes it possible to qualify the links observed and to understand the structuring of some of the thesis committees in our study. This article advocates a close articulation between quantitative and qualitative practices in STS; we therefore follow the path outlined by Leydesdorff, Ràfols and Milojević (2020). This is why we do not separate, in the analysis, the study of co-publications from the concrete conditions of their realisation.

The first part of this article examines the previous attempts to characterize the scientific community and graduates' admission, carried out in Sciences and Technology Studies. The second part details the material collected, explains the method used to process it and provides a general description of the data. The third part is an analysis of the various co-publishing networks, which permits to single out the formation of structured peer communities for the purpose of PhD validation.

2 A community and its candidates

2.1 Organisation of the scientific community: in-between hierarchies and networks

The organisation of the scientific community (and of its disciplinary components) has been the object of numerous socio-historical studies which have demonstrated the importance of the "entry fee" and the way social boundaries are quickly delineated (Mullins, 1972). The position occupied by PhD studies has often been studied by sociologists of science from the perspective of the hierarchic relationships between supervisors and their PhD students. Hagstrom's work (1965) provides the twofold advantage of articulating the issue of thesis supervisor/PhD student relationships with the issue of the differences between disciplines. He describes the scientific world as rather individualistic, made up of dyadic relations governed by individualistic norms of independence. This type of relationships mostly fosters exchanges along the logics of "reciprocal gift-giving" which also characterize the PhD students/supervisors' relationships, the former complying with the latter's "domination" in return for being trained into research. However, Hagstrom insists that the forms of collaboration differ according to three types of disciplines: theoretical sciences functioning rather individually and where PhD students merely contribute to their professors' growing influence; laboratory sciences requiring assistants mastering scientific instruments; and "field" sciences which demand faraway investigations for which PhD students are extremely useful (Hagstrom, 1965: 124 and following).

Pierre Bourdieu's sociological concept of fields corroborates the way socio-epistemic relationships between PhD students and supervisors are structured. When characterizing the scientific field, Pierre Bourdieu points out that the "pretenders" or "candidates" confront "the dominant" i.e. the incumbent researchers via "antagonistic strategies". According to him, the "dominant" wish to keep their positions and all the institutions that have brought them where they are. On the other hand, candidates "may be geared towards succession strategies securing safe and rather stable positions", or "towards subversion strategies", which are riskier but whose potential benefits in terms of field redefinition are significant (Bourdieu, 1975: 103-104). Those PhD students are not yet in a position in which they can a priori define their own strategies: they are caught into power struggles, which structure their disciplinary field.

In *Homo academicus*, Bourdieu suggests carrying out studies which could "grasp the logics of the exchanges academics get involved in to form thesis committees (an academic asking a

colleague to be part of a committee for the defence of a thesis he has supervised implicitly commits to granting reciprocity, thus integrating a chain of continuous exchanges), or for the sake of elections…" (Bourdieu, 1984: 129). Terry Shinn (1998) also analyses PhD student/thesis supervisor dyadic relationships as being based on implicit reciprocity: PhD students reinforce their supervisor's power since he finds the topic and helps with publishing. Terry Shinn also demonstrates that researchers, in the course of their career, establish extensive social networks and consolidate their results through more fully developed phenomenological explorations. The social hierarchy of the scientific activity is therefore as much a hierarchy of "relationships" as a strictly cognitive hierarchy.

Network analysis is definitely a particularly fertile field to study the communities involved in research dynamics. Processing data collected by such analysis evidences some global structures which go beyond the organisational boundaries of scientific institutions – particularly all the studies on co-publishing (Newman, 2004), "invisible" communities tied up by co-affiliations (thesis committees, disciplines, languages, etc.), by citations (Milard & Tanguy, 2018) or by joint qualifications (Renisio & Zamith, 2015). Therefore, network analysis supplements more classical studies which focus on the organisation of this activity (Gingras, 1991).

In the literature, there are two types of SNA research work on the relationships established while supervising or validating a thesis: on the one hand, in 2017, Chariker and his colleagues published a network-based analysis of mentor-mentee/doctoral student-thesis supervisor relationships from the Academic Family Tree, a web-based database of theses defended over two centuries in the United States. Their analysis indicates that the pattern of Nobel laureates' mentoring relationships is non-random (Chariker *et al*., 2017). Nobel laureates had a greater number of Nobel laureate ancestors, descendants, mentees/grand mentees, and local academic family.

On the other hand, some studies (Godechot, 2016; Renisio & Zamith, 2015; Verschueren, 2016), combined an analysis of research groups through their objective relationships (co-authoring, co-supervising, etc.) with an analysis of differentiated individual positions such as PhD students in front of thesis committees. The additional advantage of these studies is to acknowledge the social and relationship component of thesis committees instead of only using the rather naïve criteria of academic excellence. According to Godechot (2016), invitations to PhD committees are an indicator of disciplinary relationship patterns through which the concept of social capital can be explored at both individual and collective levels. Concerning the EHESS[2] recruiting process, the study demonstrates that statistical links exist between the probability for a PhD student of being granted a position and her/his supervisor's network as well as that of her/his committee.

By mobilising network analysis and data on PhD committees, our article fits well into this recent line of work. It contributes to enriching this emerging field of research, by offering a comparative point of view on three disciplines with very distinct characteristics (an experimental science: astrophysics, a fundamental science: standard economics and a

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field science: archaeology), whereas the previously cited articles each focused on specific disciplines[3].

2.2 Role played by disciplines in shaping publishing practices

Our research does not concern off-ground disciplinary scientific communities but starts from PhD theses carried out in three laboratories of the same major provincial city (Toulouse)[4]:

- the Institute of Research into the Fundamental Laws of the Universe (CESR, which merged with two other laboratories into the Research Institute in Astrophysics and Planetology in 2011);
- the GREMAQ (Research Group in Mathematical and Quantitative Economics) together with the University doctoral school in economics;
- and TRACES (the Laboratory of Archaeological Research on Cultures, Spaces and Societies)[5].

We selected them along two sets of crossover criteria: first, their disciplines are very distant from one another (astrophysics, economics, archaeology). Second, they stand for three major cognitive areas (physics, social science, history). Third, they are part of three laboratories of similar importance, at least for their respective host universities (even though when compared one to the other, the gaps in size are quite noticeable); last of all, the three doctoral schools they belong to are located in Toulouse.

The three laboratories studied correspond to three disciplines. Therefore, we have to clarify what is meant by discipline. Yves Gingras (1991) listed the characteristics of disciplines (as opposed to professionalization); a discipline is characterized by its practice, its institutionalization (via reproduction and dissemination systems) and the development of a social identity (which may overlap with professionalization) (Gingras, 1991). Disciplines are altogether a knowledge base, some know-how, orthodox references and the central base for a set of people recognized for their qualification (Knorr Cetina, 1999); disciplines are rather autonomous but remain connected to one another by a series of meta-epistemic conventions (i.e. the search for truth, the use of rational arguments, objectivity) which provide some scientific convergence.

Our analysis means to actually grasp the publishing practices of the groups studied at the very core of the specific conventions of each discipline. David Pontille, in his thesis about scientific authorship (2003) has shown that the ranking of authors characterizes the particular way a discipline organises, functions and determines socio-epistemic hierarchies. According to us, the issue of publication visibility is central to our study of co-authorship, because graduates are bound to engage into some publishing practice which both determines her/his relation to her/his discipline and her/his relationship to other more experienced researchers. By building on three laboratories and three disciplines, we attempt to account for the most marked differences (but also for the closest possible connections) existing in young candidates' practices of scientific co-authorship.

[3] Pierre Verschueren (2016) has nevertheless used the data on post-war thesis committees held in physics in Paris to show the chain existing between disciplines.

[4] By doing so, we meant to avoid the Parisian tropism, that is to say an over-representation of Parisian committee members on Parisian thesis defences, and to make it easier to conduct interviews with PhD directors since we were all based in Toulouse at the time when this research was done.

[5] We also started looking at theses defended in another social science laboratory of Toulouse 2 University (FRAMESPA for "Southern France and Spain: history of societies from the Middle Ages up to nowadays") but collecting theses defended over the selected period in this laboratory of history looked quite difficult.

The differences in collaborative practices (the more or less great number of co-publishers) depend on the specific epistemic concerns structuring each of the disciplines. In astrophysics, the instrumental dimension comes first and requires that teams should work on common subjects or shared techniques. Less systematically so, archaeology and its field constraints also imply collaborative practices. Economics is more humanities or fundamental mathematics oriented (Hagstrom, 1964) and values individual production.

As shown below, we found that this overall organisation of publication modalities in astrophysics, archaeology and economics was actually the case (as demonstrated in our study) and should be contemplated as the background to the various specific patterns of co-publishing practices as instantiated at the time of a thesis defence.

3 Data and methods

3.1 Data collection

Although our research focuses on the thesis as standing for a specific writing moment in the young candidates' experience, our sampling design is longitudinal. We have built a comprehensive corpus of theses defended in each of the three laboratories over the 2003-2008 periods (that is before the new norms for committee composition along the 2009 reform, which imposed parity between local and outside members). The data collected concern PhD students (either via their curricula on the laboratory websites, or, sometimes, by contacting them). Using thesis covers and laboratory databases, we pieced together the committees and collected information about each member's status (professor, researcher-lecturer, CNRS researcher, other), teaching and/or research place, nationality (taking in supervisors from foreign committees), and their publications (whether co-publishing with PhD students or another member of the committee – focus of our analysis – as well as their overall publishing profile).

Second, we carried out some systematic research concerning PhD students' co-publications with the members of their committee. In order to build up our corpus, we first used public bibliometric data. In the case of the Institute in Astrophysics and Planetology we used the NASA/Astrophysics Data System base, which collects articles published in astronomy, astrophysics, physics and geophysics (that is to say all the Institute in Astrophysics and Planetology disciplines). Concerning the doctoral school of economics (together with the GREMAQ laboratory), we drew on the ECONPAPERS database (which collects over 800000 articles in economics). As for TRACES, we used the French database DAPHNE (Data in Archaeology, Prehistory and History on the Web), which provides bibliography information convergence.

Obviously, it may be objected that the use of three different databases might have biased our analysis. But we did not choose to draw on a single database (the Web of Science for example), first because this type of multidisciplinary database tends to over-represent some disciplines (particularly in the field of physics and natural sciences) at the expense of others (especially historical sciences). On the other hand, for the sake of balance, the Web of Science database was tested to assess the differences with the bases chosen: the specific databases we used proved systematically better stocked. We opted for accurate corpora and preferred to conform to the usual publishing practices in these disciplines. Moreover, although we limited the thesis chronotope to the 2003-2008 periods, we did not set any time limits to PhD students' –

committee members' co-publications. Selecting theses defended at that time enabled us to observe ex-post publications up to 2012.

A database was built on the information collected from both PhD students and committee members. Thus, we collected the number of publications of each PhD student as well as the number of each member. In addition to these individual data, we collected relational data concerning the number of co-publications between committee members, the number of co-publications between committee members and PhD students. Then, we listed those who were thus interconnected through their co-publications.

A series of 10 interviews (eight with economists carried out by Author 1, one with an astrophysicist by Author 2 and one with an archaeologist by Author 1) complemented our statistical data so as to confront researchers to the networks exposed by their co-publications. This exercise clarified several aspects concerning the way local teams got structured.

3.2 Descriptive analysis

Table 1 below presents descriptive statistics concerning our corpus of theses, about PhD students.

Table 1. Data on the PhD Students and their thesis committees

	Data	Astrophysics	Archaeology	Economics
PhD students	Number of PhD theses	34	22	65
	Number of men among the PhD students	28	14	40
	Number of PhD students having at least published one academic paper	34	11	46
	Number of PhD students who became tenured	50%	78.6%	47.7%

For the same period (2003-2008), the number of theses per discipline is therefore different (34, 22 and 65), which is consistent with the difference in size of the three laboratories. When focusing on PhD students, there are both heterogeneous publishing practices which will be commented on later on (all the PhD students in astrophysics had published one article) and diverging professional careers: half of the astrophysicists and economists did not become researcher-lecturers or researchers with a tenured position.

3.2.1 Committee members

From CVs on the laboratory websites, we collected some statistics (nationality, age, place of education) concerning the supervisors hereafter presented. Our set of extended data characterizes the overall composition of committees per laboratory and so per discipline, in the Table 2 below.

Table 2. Data on thesis committees

Data	Astrophysics	Archaeology	Economics
Total number of committee members	152 (34 theses)	85 (22 theses)	163 (65 theses)
Participation frequency (total number of committee members/ total number of PhD thesis)	4.5	3.8	2.5
% of men	82%	90%	90%
% of members affiliated to a French institution	82%	88%	44%
Year of birth (median) and standard deviation	1954 9 years	1948 7 years	1960 7 years
Median number of committee members/jury	7	6	5

Our sample of theses defended in economics displays an almost exclusive majority of male supervisors rather European but not local. The median year of birth is 1960 with rather lowstandard deviation. They supervised an average of 5 theses over the period considered (2003-2008).

In astrophysics, female supervisors are more numerous. Therefore, this group looks more local than the previous. Astrophysics is singled out by the total number of committee members (higher than the archaeologists and economists) and the bigger size of their committees (an average of 6.6 members per jury). Over the period, each supervisor supervised an average of 1.5 theses.

In archaeology, our corpus comprises 9 PhD supervisors among whom 3 women. They supervised an average of 2.7 theses with a standard deviation of 2. In the group, one supervisor supervised 10 theses. Committee members were born around 1948.

3.2.2 Co-publishing

Before presenting our analyses from the data collected in the three Toulouse laboratories, it is necessary to briefly introduce the publication practices in the three disciplines of our corpus (number of co-authors, number of publications). In astrophysics, the average number of authors per publication is 31.8 (with a median number of 11 co-authors). It is only 7.6 in archaeology (with a median number of 4 co-authors) and only 2.71 in economics (with a median number of 3 co-authors). These co-publishing collaborations are shaped by factors linked to common practices, common both to each of the disciplines and to their research communities and not specific to the PhD students or to the committee members of our corpus.
Similarly, the average number of co-publications per researcher in each of the three disciplines is disproportionate: 14.4 in astrophysics against 2.8 in archaeology and 2.6 in economics. It shows that research in astrophysics is far more collaborative (11 times as much as in economics) but also more prolific (5 times as much as economics) than the other two disciplines which share similar characteristics of scientific production criteria.

Let us start with the global co-publishing modes between PhD students and their committee and supervisor. In economics, 65 theses were defended and in 46 of them, with a PhD committee co-publication (i.e. 70.7%). In archaeology, out of the 22 theses defended, 11 led to co-publications (i.e. 50%). Last of all, in astrophysics all the theses (*n = 34*) were accompanied by a co-publication: This is a standard approach to work in astrophysics where theses are most often made up of a series of already published articles or about to be published (Table 1).

In our study, co-publishing practices between PhD students and committee members, then between committee members themselves, are seen as evidencing collaborations. These publishing practices precede the thesis defence and concentrate the social relations which are the very object of our study. Co-publishing involves a specific mode of socializing within the scientific community: it implies some epistemic and sometimes hierarchical proximity in the case of PhD students and thesis supervisors. Our sample of PhD students and committee members has enabled us to collect their co-publications so as to establish the following statistics (Table 3).

Our sample of PhD students is characterized by a big difference in the number of publications between astrophysics and archaeology compared with economics which is less prolific. But the fact that the Institute in Astrophysics and Planetology depends on the thesis charter of the doctoral school which imposes candidates to publish articles that will make up the body of their thesis should be taken into account. In other words, the publishing process itself is "encapsulated" in the thesis sequence[6]. Then, the observation of the PhD students' co-publications with members of their committee and with their supervisor reveals that both archaeology and economics break away from the more collaborative model in astrophysics.

Co-publishing between committee members in astrophysics (43.74) is thus much more important and more collaborative than in the two other disciplines (Table 3). At the Institute in Astrophysics and Planetology, the salience of major space projects (the most recent being the satellite Planck) which associates instrumental platforms and the abundance of results also account for the great number of co-signed publications.

In terms of co-publishing, archaeology is in-between astrophysics and economics. Their relation to fieldwork (necessarily implying collaborative work) may account for this particular type of publishing practice. One of the former directors of the laboratory TRACES and supervisor of numerous theses explained that the specific fieldwork logics (i.e. pairing mixed methods) definitely characterizes archaeological work:

"*What I've always loved about archaeology is that you are right at the confluence between literature and history, to me, history is part of literature, a particular form of literature and life and natural sciences, geology archaeozoology, history, all of them mixed up and so, it's fascinating because you deal with everything, historians love it, it's their calling (…), we do make everything by ourselves, our documents, field, material, objects, there are no instructions for us, an object is found and we have to invent our instruction manual, you*

[6] There is no such requirement in economics. The GREMAQ activity reports over the studied period do not mention any rules concerning the doctoral School.

experience such joy when you find, propose interpretations, nevertheless always based on scientific reasoning".

Therefore, archaeology is not "instrumental" like astrophysics (in this discipline, platforms require an accurate distribution of tasks), but it conjures up the "do-it-yourself" practice identified by Claude Lévi-Strauss to single out practices combining material, methods and heterogeneous approaches (Lévi-Strauss, 1966).

Table 3. Co-publications of doctoral students and members of their thesis juries

	Disciplines	Astrophysics	Archaeology	Economics
PhD students	Number of theses	34	22	65
	Median number of publications per PhD student	10	5	4
Co-publications*	Total number of co-publications	2687	367	607
	Total number of co-publications/ number of authors (including the PhD student)	14.4	2.8	2.66
	% of jury members with whom the doctoral student has published	54%	8.5%	14%
	Number of co-publications between the PhD student and his/her supervisor/ total number of co-publications	13.62	0.59	1.05
	Share of co-publications between the PhD student and his/her supervisor on all its publications	84%	4.1%	11%
	Number of co-publications between committee members/ total number of co-publications	43.74	8.68	5.35

* The co-publications taken into account are those that involved at least two members of the same committee (including the thesis director) and those that involved the doctoral student with at least one of the members of his/her committee jury. The periods taken into account are respectively 1970-2011, 1972-2011 and 1974-2011.

Even if mathematization plays an increasing part in economics, co-publishing seems to rely on common research work based on models mastered by some teams made up of 2 or 3 people. It means that scientific citations reinforce relationships, hence committee membership invitations are then "taken for granted" by the researchers involved as part of their scientific exchanges.

About a committee member, Bruno, a CNRS research director told us: "*I've known him since…So, I first met X, I didn't know him before my thesis, he contacted me on my return back to Paris, so, I'd say I've known him since about 89 … He started inviting me here, I remember coming here for the official opening, he had invited me to the opening ceremony of the Industrial Economics Institute and, before, to one or two thesis defences at that time when you used to put on a toque, etc… For thesis committees…we've had quite a few exchanges, we used to discuss a lot, but we have never written together, we had one or two projects of articles together but we never did it...*"

The proportion of PhD students' co-publications with committee members is extremely variable and the same applies to their co-publications with thesis supervisors.
To sum up, systematic publishing in astrophysics must be interpreted in the light of the compulsory contract compelling PhD students to publish in order to be able to defend their thesis (which is not the case of the archaeologists and economists we studied) and of the more collaborative nature of space projects.

4 The invisible communities surrounding the thesis

By applying social network analysis to our data, we first constructed and analysed co-membership and next, stronger networks associating both co-membership and co-publications, from the point of view of their structural characteristics (density, configuration, average distance).

The professional relationships between scientists within their laboratory are multiple, that is to say they involve several types of collaborations, from participating in projects, sharing courses to co-publishing, committee membership, etc. In the article, the method used consists in superimposing co-membership in the same committee and co-publishing collaborations.

The network analysis of co-membership –whichever network involved– reveals that the structure of these communities almost match, at times, the structure of the laboratory (in the case of the Institute in Astrophysics and Planetology or of TRACES), at times that of the doctoral School (in the case of economics). They quite systematically reflect the laboratory teams and it is to be noted that very few committees are made up with members from different teams.

Table 4. Comparative characteristics of the 2 types of networks in the 3 disciplines

Discipline	**Astrophysics** **34 theses** **152 members**	**Archaelogy** **11 theses** **85 members**	**Economics** **65 theses** **163 members**
Co-Membership Network	609 ties density = 5.31% mean distance = 3.13	280 ties density = 7.84% mean distance = 2.61	1180 ties density = 4.5% mean distance = 2.9
Co-Membership Network and co-publications network	227 ties density = 2% mean distance = 5.5	67 ties density = 1.88% mean distance = 2.63	168 ties density = 0.7% mean distance = 4.17
Share of common relations between the 2 networks	37%	32%	14.23%

4.1 Co-membership networks and co-publishing networks

We have successively analysed the three disciplines in the three Toulouse laboratories: astrophysics, archaeology and economics. For each discipline, committee co-membership comes first, followed by that of co-membership paired with co-publishing. Dealing with co-membership networks, the tie taken into account is “X and Y share the same jury”. This has nothing to do with the nature of the social relationships that may exist between the two members: one might have supervised the other, one might be the latter’s laboratory colleague, they might know each other very well and be friends, etc. On the contrary, the second tie points to strong relationships of shared research work intensified by committee membership.

4.1.1 Astrophysics

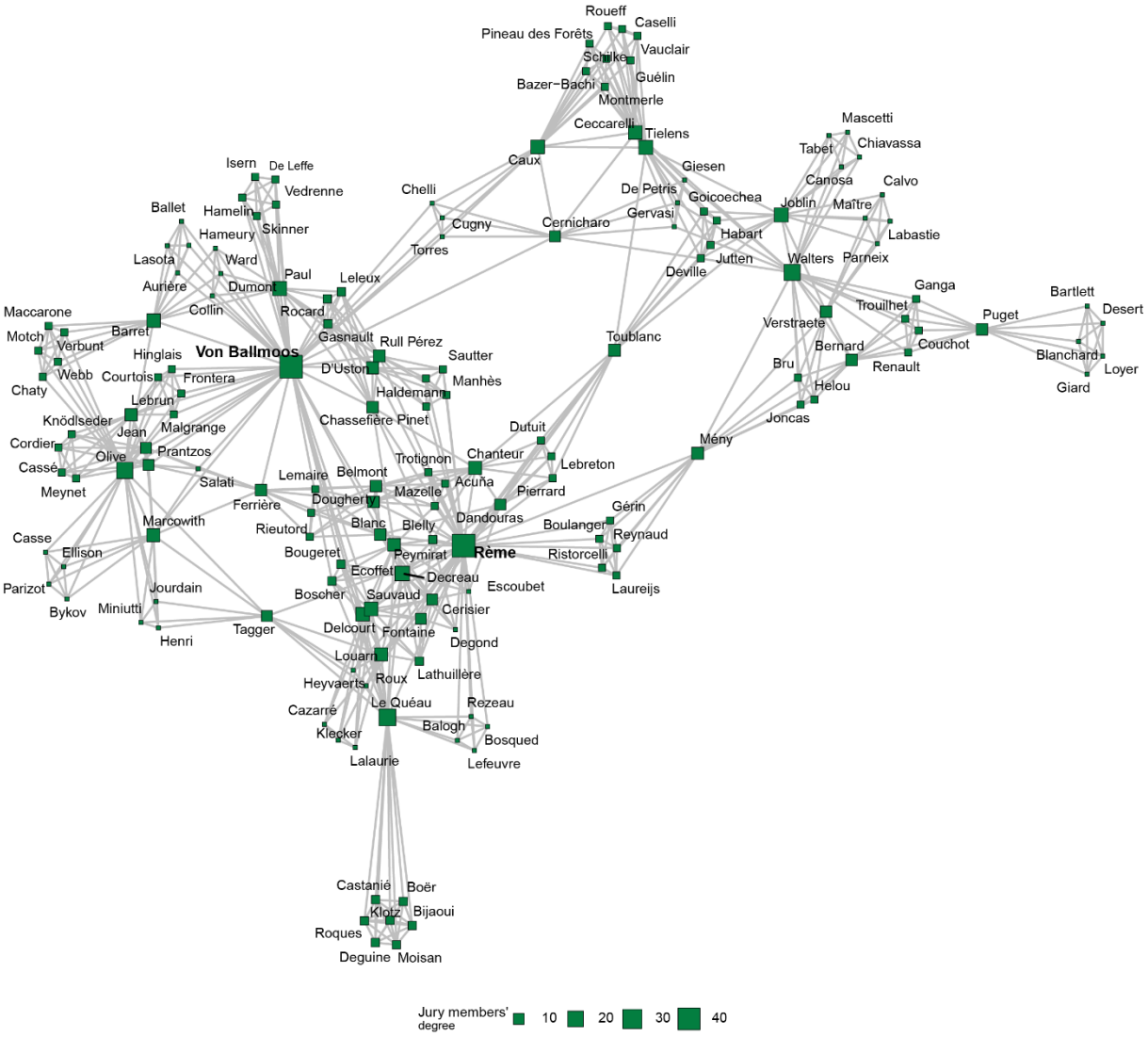

Figure 1. Co-membership in astrophysics

The co-membership network in astrophysics (Figure 1) displays three components around three researchers (Von Balmoos, Rème et Walters) among which the first two are structurally equivalent and the most central. The third one is less dense. One can make out an axis of oblique symmetry going through two researchers (Walters, Le Quéau), the most central researchers after the first two.

When co-membership and co-publishing networks in astrophysics are overlaid (Figure 2), the previous structure remains salient, as if the extra "co-publishing with" relation did not appear as a strong constraint: it merely intensifies the previous type of collaboration.

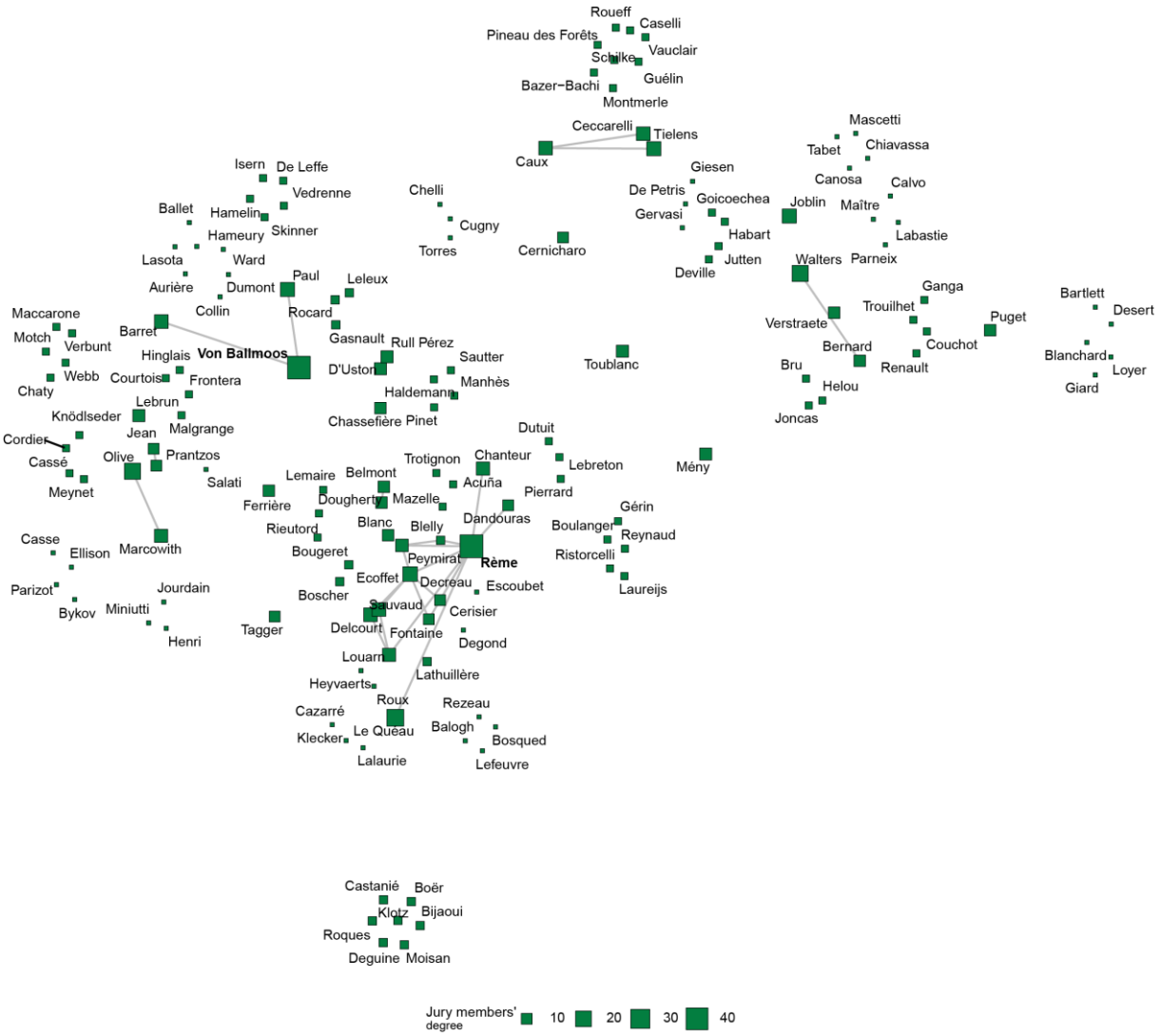

Figure 2. Committee co-membership and co-publishing network in astrophysics

The co-membership and co-publishing network in astrophysics (Figure 2) shows strong homogeneity of specialities in the formation of the candidates' publishing environment. Team specialities and their themes of study are key elements and tend to isolate co-publishers from the same laboratory.

This network contains 152 members and 609 ties and only one component, which is rather striking: all the Institute in Astrophysics and Planetology committee members are indirectly interconnected. The network density is 5.31% and the average distance between two members is 3.13, which is rather weak.

Two supervisors in the network stand out: Henri Rème and Peter Von Ballmoos who are respectively connected with 29% and 28% of the sample, i.e. 44 and 43 persons, who are not only thesis supervisors but also team leaders in the Institute in Astrophysics and Planetology laboratory. The other professors are interconnected with between 3% and 15% of the sample. Rème and Von Ballmoos also hold the most intermediary positions in the network (43% of the network paths go through von Ballmoos and 29% through

Rème). It may be noted that these two professors participate to the highest number of committees: 10 for Rème and 8 for Von Ballmoos.

To avoid over-emphasizing co-membership ties that might prove occasional, hence rather weak, it is necessary to raise the selection threshold up to co-membership at several committees. On Figure 3, the tie is "X shares several thesis committees with Y". The number of ties greatly decreases, down to a maximum of 3 common committees for two professors. The professors are thus rarely associated more than once.

The network is made up of 6 components away from a larger group structured around 13 other researchers.

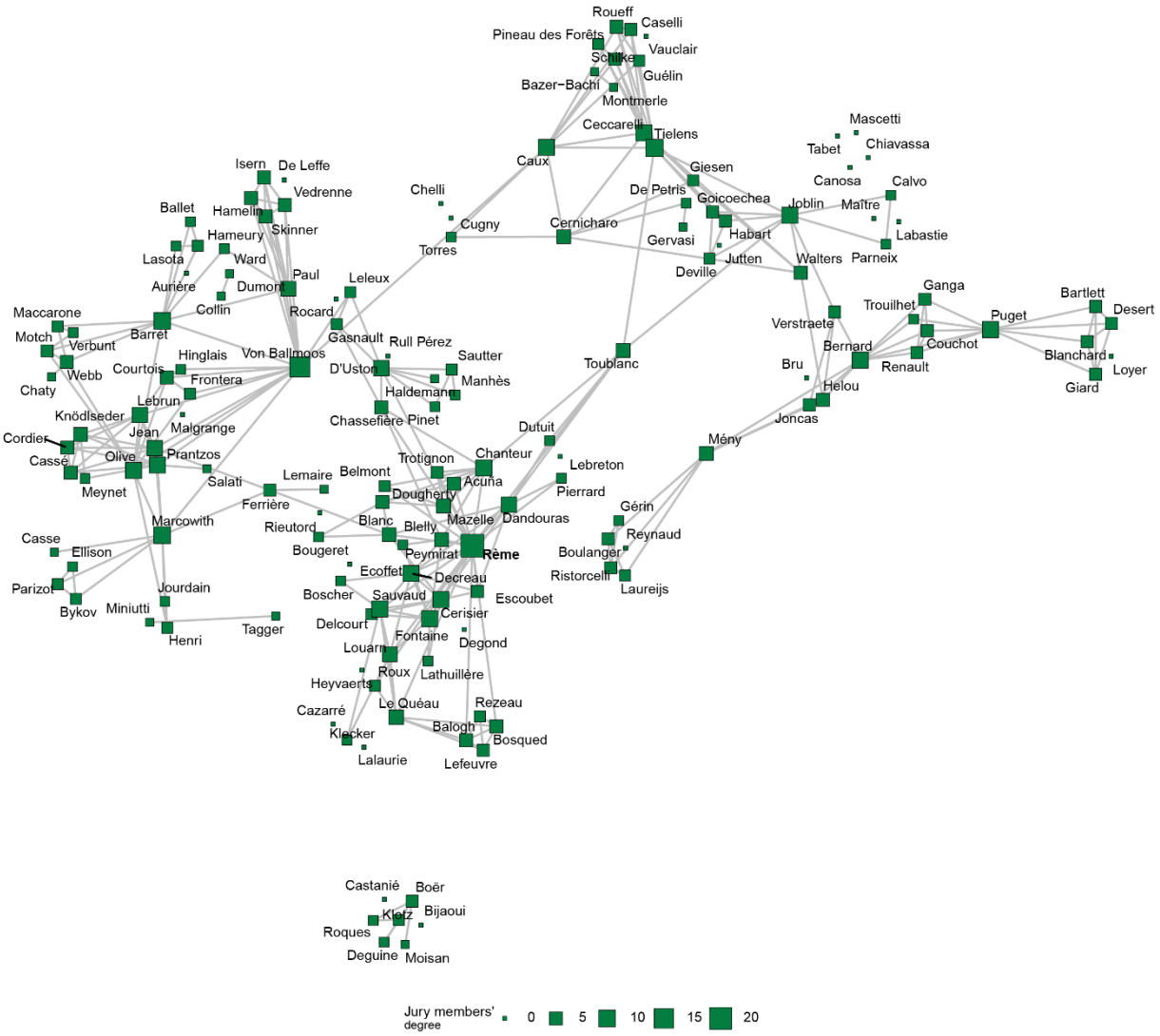

Figure 3. Network of committee co-membership on a minimum of two thesis committees in astrophysics

By only keeping the ties with Rème and Von Ballmoos (Figure 4), only those professors sharing co-membership with at least one of the two are selected: they are exactly 79 out of 149, which amounts to 53% of the total. Henri Rème chaired 9 juries of all these theses and supervised a thesis only once. Peter Von Ballmoos also chaired 5 committees, supervised 2 theses and was only once a simple member. They are definitely far ahead of

the other members and they also participated to the greatest number of thesis committees.

In the course of an interview with one of the Institute in Astrophysics and Planetology team leaders (Henri Reme), he told us that he did not share any collaboration with Van Ballmoos, as they worked on "completely different subjects". He added: "Peter is my friend, but there is no reason for publishing together" [7]. Van Ballmoos works in the field of high-energy astrophysics while Reme works on interactions in the upper atmosphere.

When co-publishing criteria are included, the two subgraphs come apart: most of the ties remain, but it is to be noted that none of the 8 professors on the same thesis committees as Rème and Von Ballmoos co-published with the two of them. Among the eight, 5 co-published with Rème et 3 did not publish with either. One can see that Rème seems to have co-published with the highest number of researchers.

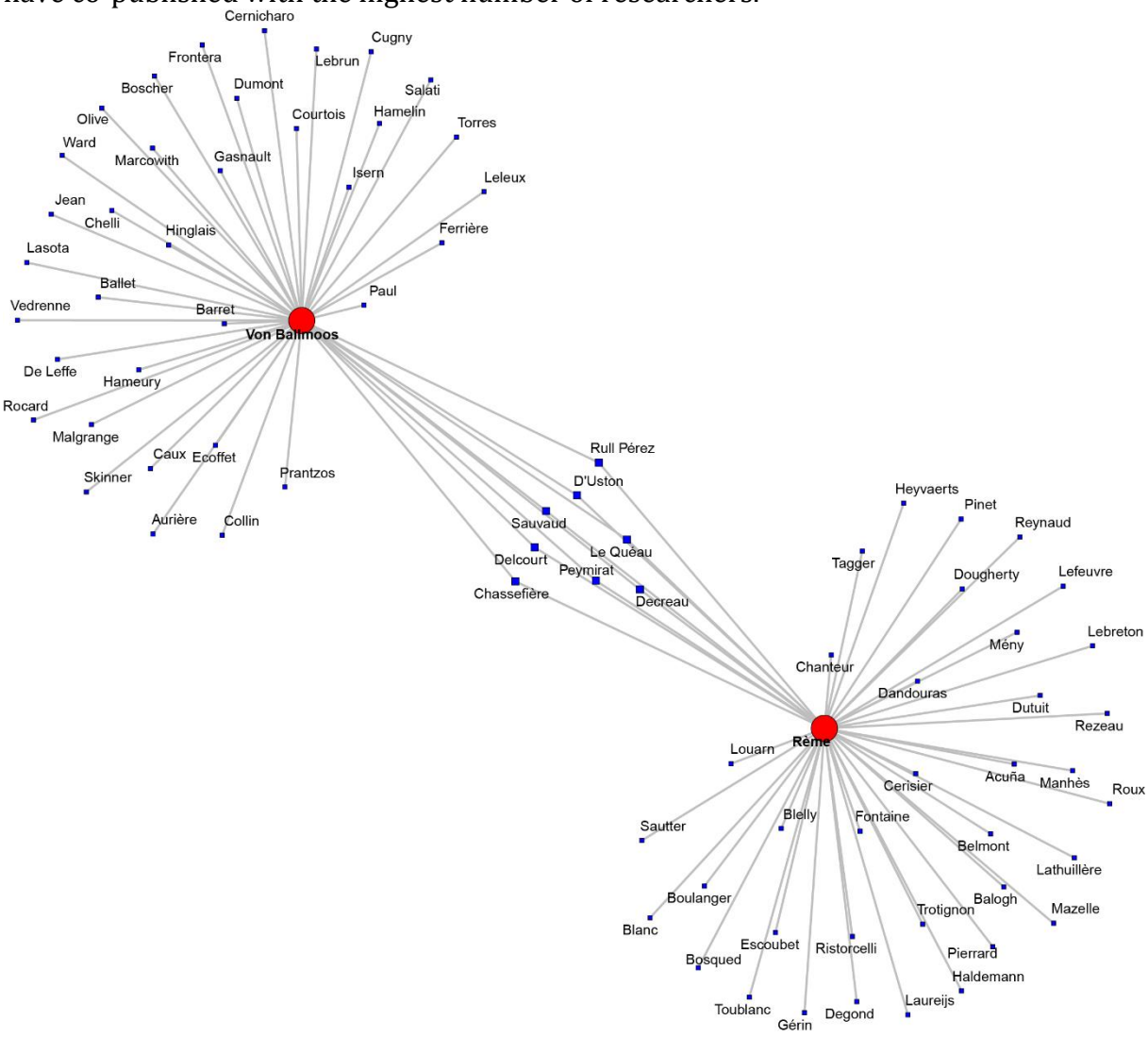

Figure 4. Graph of the co-membership ties of the two most central committee members

[7] Interview with Henri Rème, 22 June 2011.

4.1.2 Archaeology

In the case of thesis defence co-membership (Figure 5), each committee displays a minimum of three ties. The network density (that is to say the total number of possible ties divided by the total number of actual ties) is 7.84% (280 ties for 85 members). Average distance is 2.61, i.e. going from one member to the other requires an average of 2.61 intermediaries. It can also be observed that a group of five people (Senac, Rendu, Cursente, Barraud, Bolos) is cut off from the rest of the committees. It means that this group of five researchers participated to the same committee, but that none of them participated to another committee with one of the other sample members.

No wonder Yvan Pailler and Michel Barbaza hold the most central position as both of them are supervisors and participated to the greatest number of committees, respectively 10 and 6. During an interview with Michel Barbaza (09/03/2017), he wondered at the ties existing with the group of researchers, Badillo, Perrot, Helly or Ferjaoui whose names he did not know. And yet, this set connects the two bottom and top sub-components of the network. This observation calls for caution: some relationships between committee members happen to be circumstantial and temporary. All the ties displayed do not necessary imply strong epistemic involvement. They may also be the result of incidental opportunities: a committee member may represent a circumstantial compromise.

The network of stronger ties between committee members (Figure 6) actually provides 3 isolated and not very dense components around 3 central professors from TRACES.

It should be noted that co-membership to, at least, two thesis committees in archaeology is much more occasional as it leaves us with 21 ties, that is 0.6% density. The maximum number of common committees for two members amounts to 3. The new network includes 3 components around 3 main TRACES professors, Barbaza, Pailler and Sablayrolles.

When one of them was asked what accounts for his choice of inviting this or that colleague to a thesis committee, he answered that:

"*the teaching or research staff, the pool (for thesis committees) is rather limited, above all at that time of the year, you are bound to know everybody, we've got great relationships with Paris I, Bordeaux, with Aix-en-Provence, even though things are less smooth with the latter, we enjoy tight social, friendly, tactical and scientific relationships, of course, one should try…, whenever possible, you know, to coordinate so that it doesn't look like convenience committees that we'd arrange together, it may be the case, back then it did happen, it's more difficult now, back then you just did whatever you wanted to do with theses, when I think of all the constraints we have today*".

That was how he used many "strategies", more particularly to ensure the stability of the laboratory's relationships with "those in Paris" and with the Ministère de la Culture. Concerning more specifically thesis committees and their composition, he finally listed four criteria without prioritising them: he first justified invitations by referring to the researcher's expertise and specialization. He next mentioned strong budgetary constraints forcing him to finalize juries by resorting to "cheap people" from Bordeaux, Carcassonne or Toulouse (since the train ticket is cheaper to come from these

surrounding places than from Paris). He third pointed out to some "polite invitations" for Spanish researchers. Last of all, he remarked that working relationships with Paris had undergone some changes "before, Toulouse was too small to be attractive and those in Paris were rather reluctant to move whereas provincials would more easily go Paris, now things have slightly changed".

In short, finding the right sort of arrangement between keeping up relationships, holding up scientific requirements and preserving friendships is the thesis supervisor's main task to ensure a positive defence in archaeology. The challenge consists in holding together heterogeneous logics (i.e. keeping or developing personal relationships may stand in contradiction with requiring the appropriate scientific level), while taking into account the whole set of institutional, political, personal and epistemic constraints.

The co-membership and co-publication network in archaeology (Figure 7) shows that 35 members had never co-published with any other member of the same committee. The network only displays 67 ties, which corresponds to 1.88% density. Co-membership within the same committee is represented by 280 ties. Therefore, this means that 32% of co-membership ties within the same committee are also co-publishing ties. Average distance is 2.63.

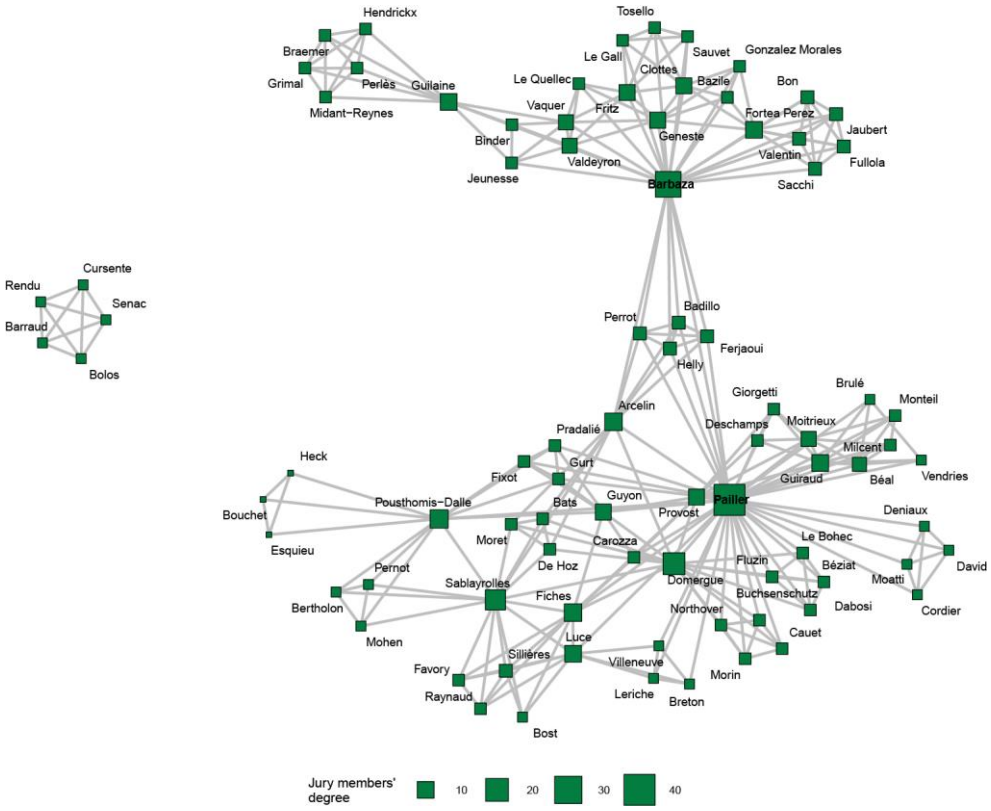

Figure 5: Committee co-membership network in archaeology

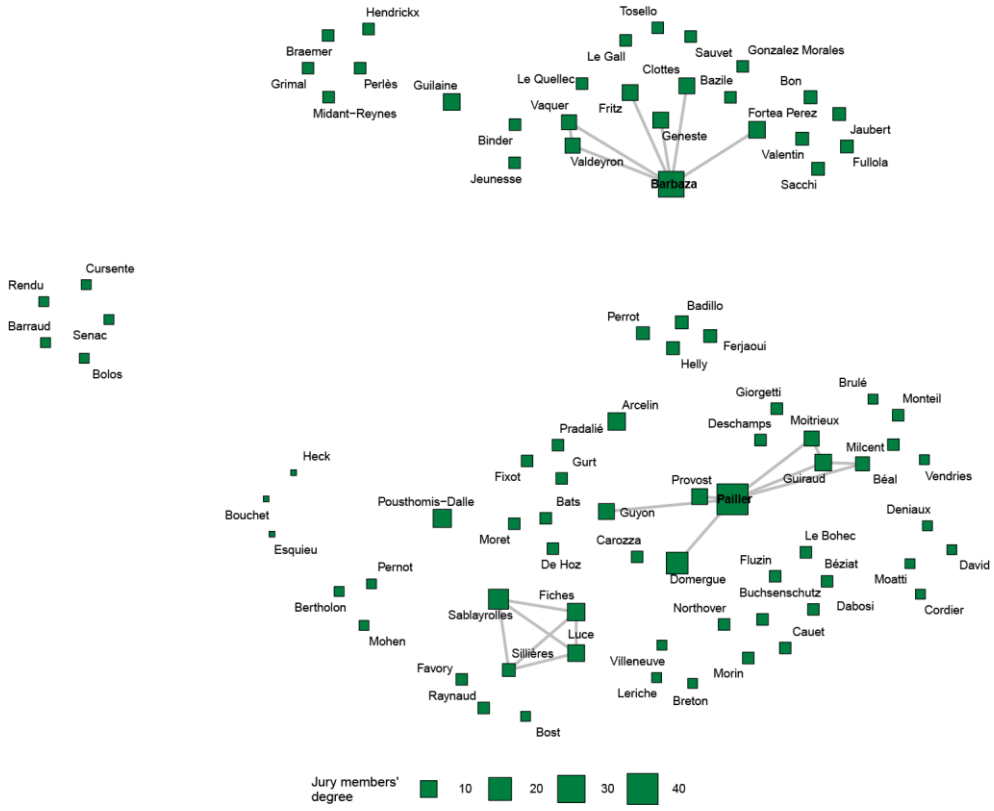

Figure 6: Network of co-membership on, at least, two thesis committees in archaeology:

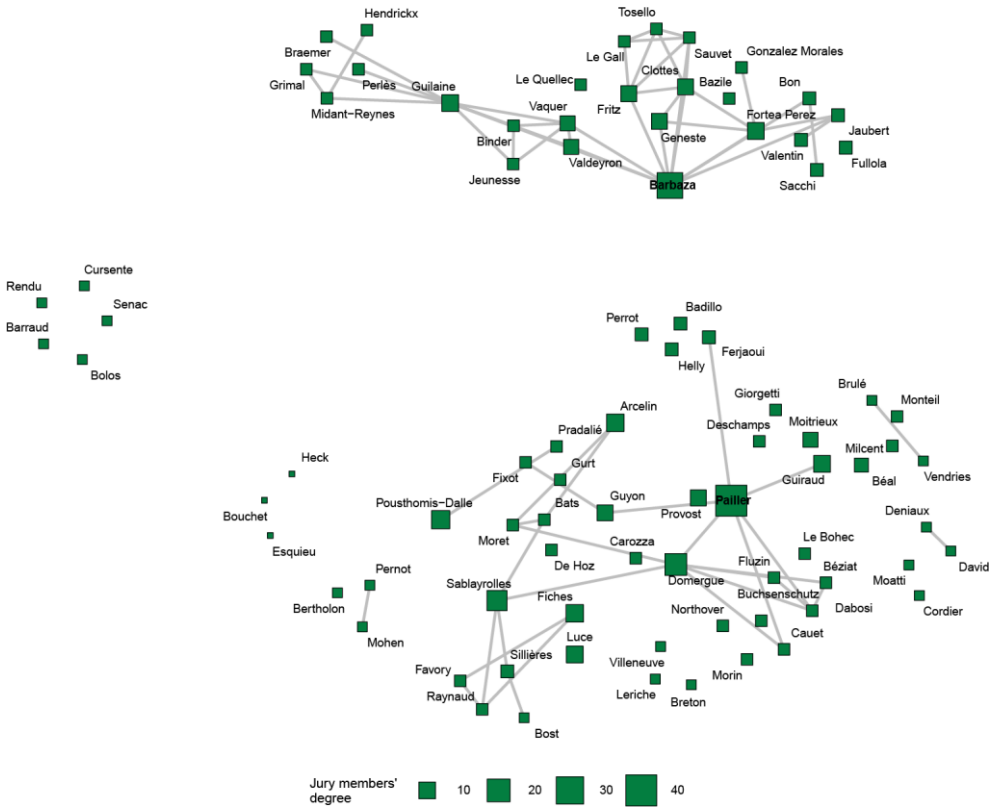

Figure 7. Committee co-membership and co-publication network in archaeology.

4.1.3 Economics

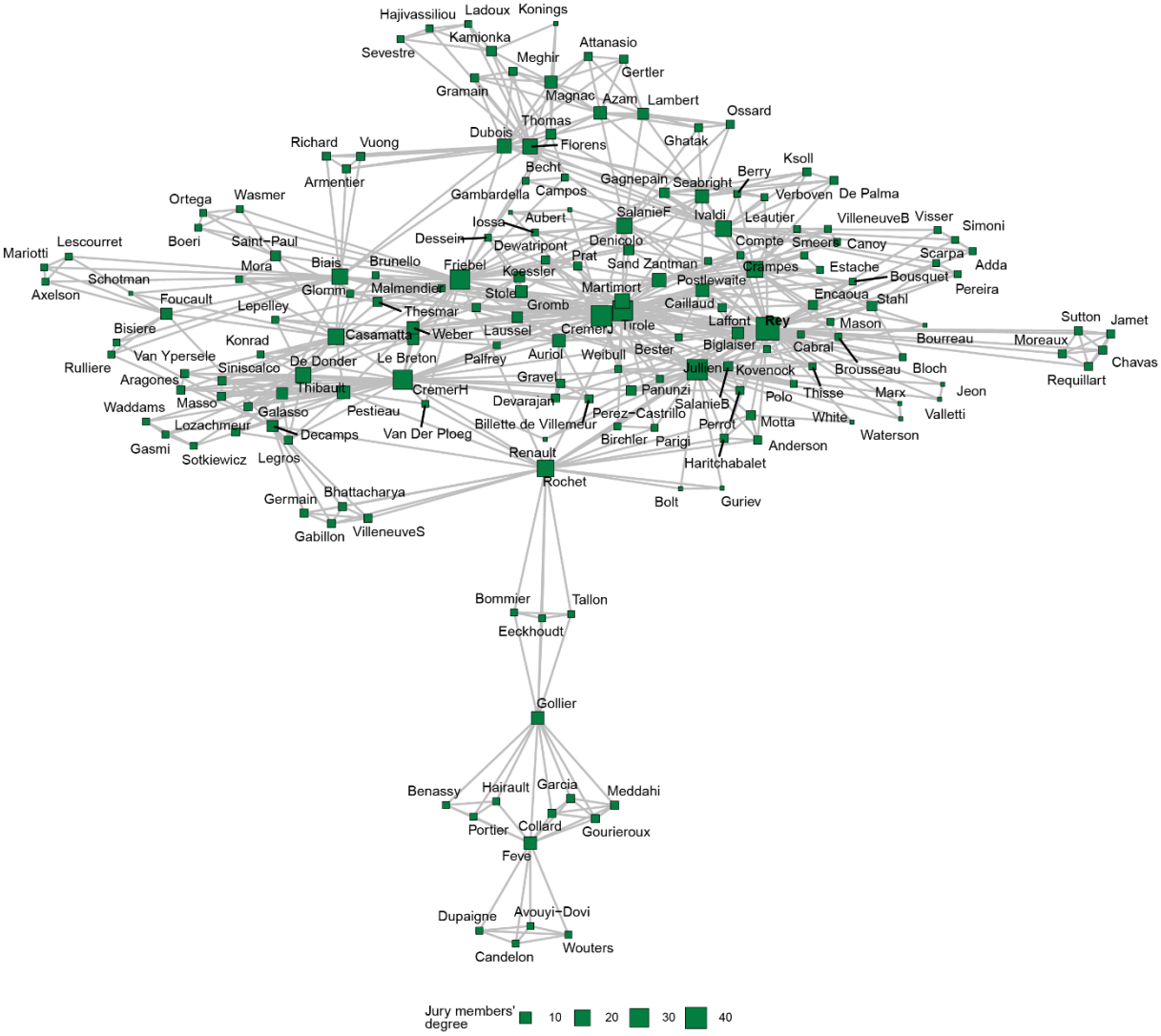

Figure 8. Committee co-membership network in economics

Concerning co-membership to a thesis defence in economics (Figure 8), each member has at least two ties. There are 163 members and 1180 ties. Hence, density is 4.5%. Average distance is 2.9, which means that going from a member to another implies an average of 2.9 intermediaries.

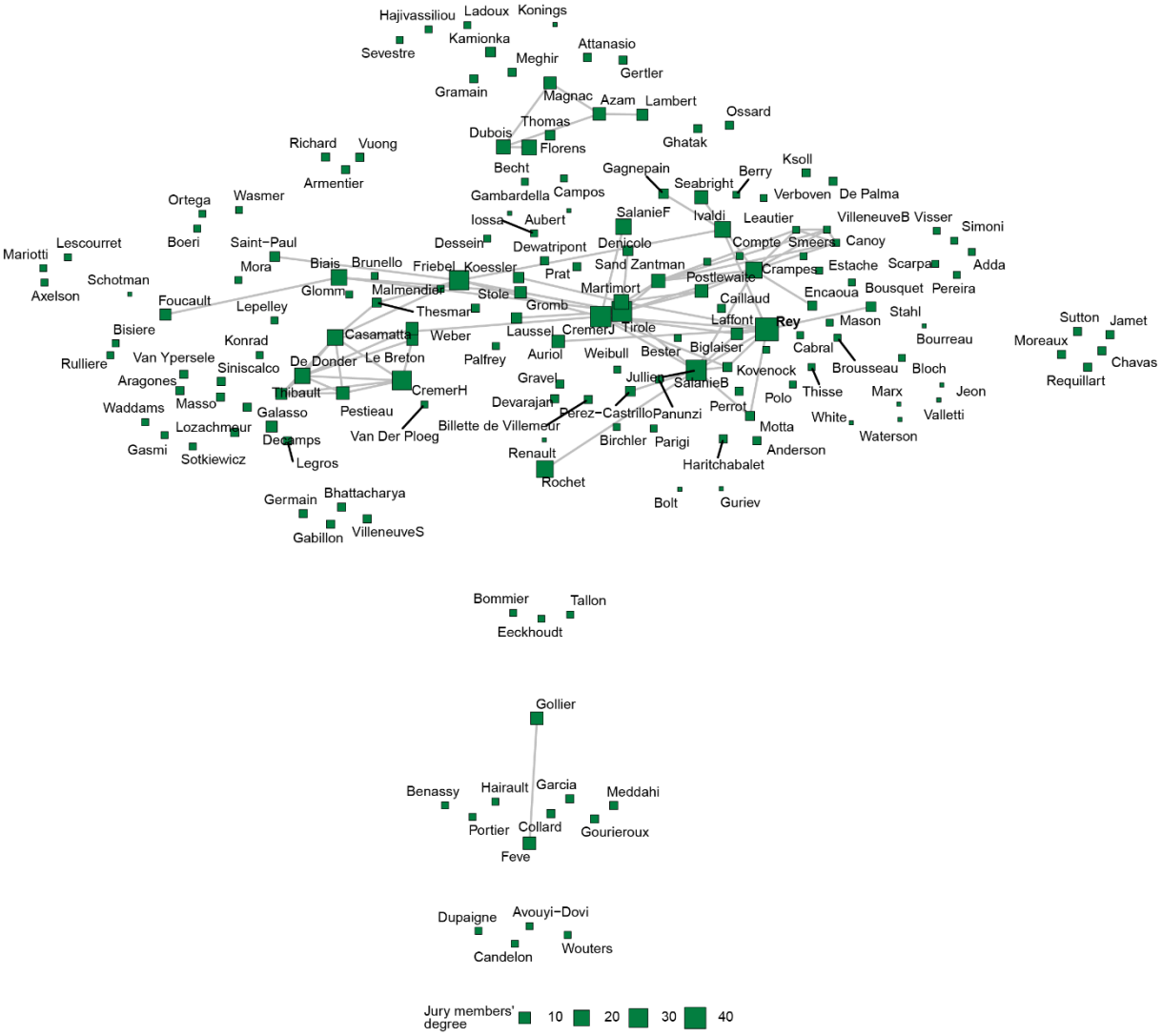

Figure 9. Network of co-membership on, at least, two thesis committees in economics:

The network of co-membership on, at least, two thesis committees in economics (Figure 9) displays those researchers who attended several thesis committees (at least two) together. It is no surprise to see that quite a number of ties have vanished. The network density is no more than 0.6% (152 ties) and three components stand out, the main one being around Jean Tirole but with a rather low local density.

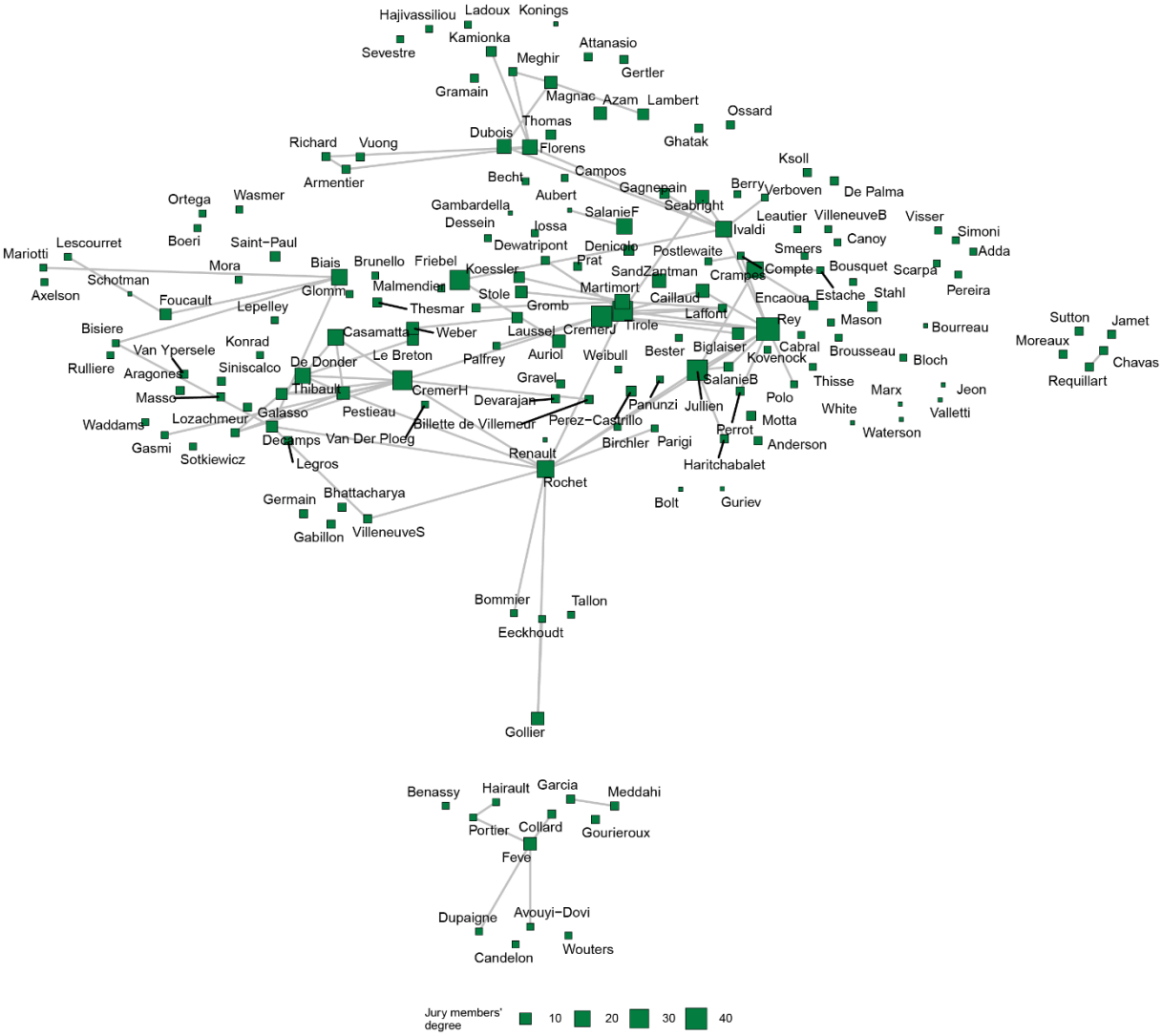

Figure 10. Co-publication and committee co-membership network in economics

When co-publication and co-membership at a thesis defence in economics are paired up (Figure 10), there are far less ties than in the co-membership network only. The network density is 0.7% i.e.168 ties, whereas the co-membership network has 1180, which means only 14% of the ties remain in the co-publishing network. Average distance is 4.17.

A series of 8 interviews conducted in 2013 with some of the economists of our corpus helped specify the part played by co-publishing between committee members and PhD students[8]. These interviews throw some light on their own career path (thesis, post-doc, successive positions, etc.), on research training practices through supervising theses and co-publishing with PhD students. Concerning co-publishing between supervisors and PhD students, three recurring practices stand out.

On the one hand, it is usual that each thesis chapter should be the version of an article already published sometimes with the supervisor or with another laboratory member. The thesis therefore condenses publishing practices. Secondly, it is common practice to provide a PhD

[8] These interviews were carried out by Author 1 as part of a research program, funded by the Agence Nationale de la Recherche, conducted by Béatrice Milard, between 2012 and 2015, studying citations of scientific articles (Milard, 2014).

student worth encouraging with a one-year research contract to help him valorise her/his thesis into an article which will also be co-authored by her/his supervisor. And yet, supervisor-PhD student co-publishing is not systematic and appears to depend on the supervisor's involvement in the thesis. For instance, Alban explained that the work he shared with one of his PhD students consisted in sharing tasks and competences: they were exploring a research area little studied so far (the economics of water resources) which required devising new methods. This involvement in concrete scientific work is also advocated by Michel as the usual norm. Talking about an article co-written with a PhD student, he said that "*in economics, supervision is usually much more than merely brainstorming ideas. It is actually real collaboration. Not for all the chapters, you hope that the student will be fully autonomous for a number of chapters, but, it's true that, at the beginning, or with some chapters, it is quite common to see both of them together, the professor working really hard, as much as the student to try and train her/him… This is what happened then*". The educational dimension adds to the original scientific work. It is about learning to be a researcher by co-working with one's supervisor.

Last of all, all these interviews demonstrated that the economists shared the same approach to supervision as facilitating students 'entry into the academic field as well as a time for acquiring research rules (article format, growing generalization, theorization …).

Talking about supervision relationships, a researcher refered to "filial" bonds between researchers and PhD students. He explicitly developed this idea when alluding to an article co-written with two other colleagues (Herbert, Luigi): "*There is a kind of lineage in connection with the thesis, Luigi was Herbert' PhD, Herbert was Pierre' PhD student and I was nobody's PhD student in the group. Luigi is Colombian, he defended his thesis here, he is now a professor, or the equivalent of assistant professor in Bogota, in Colombia and back then he would often come back to Toulouse to carry on everything he had started here"*.

If there is no compulsory lineage in economics like in astrophysics, the logic of co-publishing remains fundamental to encourage an early career. This implies that the supervisor has noticed the graduate's potential qualities and has somehow forecasted her/his future as a researcher. But this is not systematic, as opposed to what happens in astrophysics where writing a thesis necessarily implies being committed to publishing – in most cases with the supervisor in charge of the research project.

4.2 Comparing networks

Co-membership and co-publishing networks reveal two forms of socio-epistemic relationships. Co-membership indicates loose relatedness, extended affinities. Co-publishing signals close relationships and shared practices, subjects, themes and issues. In our analysis of the way committees participate to developing a form of sociability, it is necessary to grasp the specific characteristics of these two types of networks in the three disciplines.

The results from co-membership networks show that density is higher in archaeology than in the other disciplines, that is to say, concentration is more important or fewer committees are more frequent. Besides, in archaeology, the average distance between two members is shorter: which means it is a "smaller world" in which a great number of researchers have been invited to the same thesis committee. In astrophysics, density is lower but average distance is higher: the scientific community validating theses is less

concentrated. The most scattered discipline is economics but it is also the one with the greatest number of thesis committees. But even in this latter discipline, the average distance of 2.9 between two members remains short.

As for co-membership and co-publishing networks, they ought to be analysed with respect to the evolutions of indicators as compared to the first networks. Economics has lost a greater number of ties than the other two (twice as much as astrophysics and archaeology) and the result is corroborated by the very low number of common ties between the two types of networks. That is to say, committee co-membership is more frequent than co-publishing between members of the same committee. Both networks in astrophysics display the greatest similarity. Co-membership reinforces co-publishing. Archaeology stands in-between the two former disciplinary practices.

Therefore, co-membership networks and co-publishing networks single out disciplinary practices: the lack of personal connections in economics (i.e. co-membership and co-publishing hardly overlap, much less than in the other two disciplines) expresses some form of disciplinary individualism. On the contrary, in astrophysics which is based almost exclusively on vast projects requiring instruments which mobilize a great number of researchers, co-membership and co-publishing necessarily tend to tighten up.

5 Conclusion

Identifying how committee sociability is constructed enables to single out some specific academic patterns of conduct when examining members' co-membership and co-publishing practices with one another and with supervised PhD students.
It is first to be noted that disciplinary identities (despite some clear convergences) remain very strong. Co-publishing practices (unavoidable in astrophysics, less frequent in archaeology and economics) between PhD students and committee members bring to light publishing practices reflecting concrete scientific practices: collaborative work (dominant in astrophysics and in archaeology) should not be mistaken as some possible (or hypothetical) move of historical or social sciences towards hard sciences. Publishing practices are first and foremost determined by the specificity of research methods (project work, task sharing, sequencing of activities, socio-epistemic hierarchies).
The clear thematic structuring definitely turns resources into those competences committee organisers will request: members are actually selected from the largely identified stock of interpersonal relationships already secured by some possible co-publications. These two activities do not overlap as much in economics as this discipline has only few or very few collaborative research practices. Research in astrophysics is centred over vast programmes and heavy instruments, which, at least partly, accounts for the relative scientific proximity of committee members. Although the trend is less so in archaeology, collaborative fieldwork is a rallying factor which then plays a unifying role for thesis defences.
In our study, committees stand (even defectively) not only for networks of interpersonal relationships achieved through the participation in an academic ritual of integration, but also for the working communities built up by disciplines.
Finally, the peer-making process characterized here is shaped by setups that are specific to each discipline. Astrophysics, as practised at the Institute in Astrophysics and Planetology, puts co-publishing and more generally, research team work at the very core of scientific

activities dedicated to instruments (most often to satellites, massive platforms requiring numerous collaborations). Economics – above all at the highly mathematized Toulouse doctoral school– relies on a repeated methodology in the training process experienced during the thesis, which means the collaborative dimension is less important. Last of the three, in archaeology, which requires collaborative fieldwork, co-publishing is therefore quite common.

We also propose two further consequences of this network approach on the delicate phase of training for article writing and publishing via one's PhD.

On the one hand, the very heuristic nature of networks can bring to light some other elements structuring the scientific world, which other approaches cannot reveal. From this particular methodological perspective, our work is the continuation of other contemporary research using network analysis in *Science Studies* (Milard, 2014, Baccini *et al.*, 2020, for example). By combining "bibliometric data" and co-membership and co-publishing network analysis, our method reveals both the relationships which are at the background of the composition of thesis committees but also reveals the "mentors'" relationships to the PhD students they supervise or whose final research work they assess. Indeed, most studies do not highlight the social setup at work either behind the formation of committees or the work of writing. Here, the social setup distinctly pertaining to each discipline can be clearly identified as an indicator of the different disciplinary practices, more or less collaborative, more or less "guiding" for PhD students.

On the other hand, the written material (theses and articles) allows to situate the construction phase of a committee by exposing, just like in the case of citations (Milard, 2014), imprints of social relationships. Agreements passed between individuals, working relationships developed, scientific coalition engaged as well as the whole training involvement provided to young candidates are all perceptible in the various ways of co-authoring or of involving co-authors.

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Data Availability: The coauthorship and PhD thesis committees data that support the findings of this study are available in the GitHub repository https://github.com/Marion-Mai/peer-making with the Zenodo identifier https://doi.org/10.5281/zenodo.4966081. All personal data (PhD students' and committee members' names, plus their publications' and PhD theses' titles) are available from Marion Maisonobe upon reasonable request. These data have been collected by and under the supervision of Marie-Pierre Bès.

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