



# Reconciling conflicting themes of traditionality and innovation: an application of research networks using author affiliation

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## Abstract

Innovation takes different forms: varying from path-breaking discoveries to adaptive changes that survive external shifts in the environment. Our paper investigates the nature and process of innovation in the traditional knowledge system of Ayurveda by tracing the footprints that innovation leaves in the academic research network of published papers from the PubMed database. Traditional knowledge systems defy the application of standard measures of innovation such as patents and patent citations. However, the continuity in content of these knowledge systems, which are studied using modern publication standards prescribed by academic journals, indicate a kind of adaptive innovation that we track using an author-affiliation based measure of homophily. Our investigation of this measure and its relationship with currently accepted standards of journal quality clearly shows how systems of knowledge can continue in an unbroken tradition without becoming extinct. Rather than no innovation, traditional knowledge systems evolve by adapting to modern standards of knowledge dissemination without significant alteration in their content.

**Keywords** Traditional medicine · Ayurveda · Academic research networks · Innovative potential · Affiliation-based homophily · Q measure of assortative mixing

## Introduction

One important platform for sharing knowledge, be it results of cutting-edge research or establishing old truths in a modern context, is journal publications (Thyer 2008; Edwards 2015; Sandström and van den Besselaar 2016). Medicinal sciences is of particular interest, as team collaboration is necessary to produce research outcomes (Hall et al. 2008; Gibbons 1994).<sup>1</sup> Of the existing data-sets providing details of academic collaborations and knowledge sharing in biosciences, PubMed is one of the foremost sources (Falagas et al. 2008b; McEntyre and Lipman 2001; Anders and Evans 2010). With a collection of more than 30 million citations

on biomedical literature, PubMed (maintained by the US Government funded US National library of Medicine and National Institutes of Health) offers a panorama of publications of diverse qualities and topics.

Of great interest is the simultaneous co-existence of research papers not only from the current mainstream of bio-medicine, but also other branches of medical knowledge, such as traditional medicine.<sup>2</sup> No two canons of knowledge can be as distinct from each other as bio-medicine and traditional medicine (Baars and Hamre 2017; Mukharji 2016), and yet academic collaborations conform to similar standards of dissemination of knowledge and is available in a common platform like PubMed. In terms of the character

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<sup>1</sup> The importance of team collaboration for producing quality research has been documented for other disciplines and across countries. See Adams (2013) for a general discussion on the impact of international collaborations on knowledge sharing.

<sup>2</sup> World Health Organization's Report on Traditional Medicine (2000) defines traditional medicine as "the sum total of the knowledge, skills and practices based on the theories, beliefs and experiences indigenous to different cultures, whether explicable or not, used in the maintenance of health, as well as in the prevention, diagnosis, improvement or treatment of physical and mental illnesses." This definition finds resonance in Fokunang et al. (2011).

of the discipline, bio-medicine displays masculinity,<sup>3</sup> and low power distance<sup>4</sup> whereas traditional medicine strives to retain content untouched.<sup>5</sup> The former is marked by Schumpeterian upheavals and stark innovations from time to time (such as the development of vaccines and novel drugs for treating new disease conditions,<sup>6</sup>) whereas the latter pride in their continuity of knowledge handed down from generation to generation [see Banerjee (2009), Shukla and Sinclair (2009) and Mathur (2003)]. The simultaneous existence of research papers from both disciplines for journals conforming to uniform standards of publication automatically raises questions about the true nature of innovation in traditional knowledge systems like Ayurveda. It is possible that it is an innovative discipline because it shares the same kind of research output space as bio-medicine publications. On the other hand, the nature of collaborations within the traditional knowledge journals might be ‘non-innovative’, despite publications in standard format journals.

When knowledge systems adopt the platform of journal publications, the structure of information disseminated becomes a function of the standards and rules set by them.<sup>7</sup> There are specific structural restrictions, such as bibliographies of specific types (Green 2000; Masic 2013), journal rankings (González-Pereira et al. 2010)], double-blind peer review systems (Albers et al. 2011) etc., that are imposed when knowledge is shared through journal publications. This brings us to our central query: when a medicinal system which is considered ‘traditional’ uses modern publication standards to disseminate knowledge, what kind of collaborative structures will be observed? How does a system that conforms with these modern publication standards insulate itself from dilution in terms of content and practices? To what extent will traditional knowledge systems engage with

academic collaborations as observed in other mainstream disciplines?

We contextualize our query by studying the publication network in Ayurveda, a rich traditional medicinal system prevalent in South Asia, and largely limit ourselves to the first two questions. There are other branches of traditional medicine, such as indigenous medicine of Indians in the Americas or Tibetan/Himalayan traditional medicine systems. In fact, in recent times, the coronavirus epidemic has shown the relevance of Chinese Traditional Medicine. We have evidence of successful treatment of viral cases in Wuhan, the centre of the outbreak.<sup>8</sup> The Ministry of AYUSH, Government of India,<sup>9</sup> has announced a Taskforce (in early April 2020) with members from the Indian Council of Medical Research, the Council of Scientific and Industrial Research, the Department of Biotechnology, the AYUSH ministry and the WHO (see a discussion in <https://science.thewire.in/the-sciences/ministry-of-ayush-taskforce-clinical-trials-herbs-prophylactics/>), to investigate the potential of Ayurvedic cures for coronavirus symptoms. As a prophylactic cure for COVID-19, the Taskforce has recommended clinical trial testing of some herbs, prominently Ashwagandha (*Withania Somnifera*). This herb, which we research in detail in this paper, has been mentioned in recent times as a potential alternative to hydroxychloroquine.<sup>10</sup> These efforts are in the initial stages, but the AYUSH Ministry has established a clear protocol for registering Ayurvedic formulations to establish efficacy in treating symptoms of COVID-19<sup>11</sup> as well as warning alerts to all regarding unsubstantiated claims of efficacy of herbal cures.<sup>12</sup> Traditional knowledge systems exist in modern times due to its continued relevance, despite its continued and steady referencing to historical repositories of information.

<sup>3</sup> Masculinity refers to the dominant male gender role in society reflected by “ego, performance, money and achievement” (Efrat 2014).

<sup>4</sup> Efrat (2014) define power distance as “the distribution of power within a society in terms of the degree to which its members expect and accept inequality”.

<sup>5</sup> For instance, Kudlu (2016) discusses dominance of the classical medicine market and an attempt to preserve the traditional Ayurvedic non-commercial practices in Kerala.

<sup>6</sup> Ongoing trials for COVID-19 with existing combinations of drugs which include anti-viral and anti-inflammatory medicines to treat severe cases, is an example of the nature of radical experimentation in bio-medicine (Stebbing et al. 2020).

<sup>7</sup> However, knowledge flows in a discipline are, by no means, only limited to journal publications, as books, project applications and grants (Dahlander and McFarland 2013), web-and video logs and many other forms of online and open source platforms (Yan 2014; Chesbrough 2006; Zucker et al. 2007) also contribute to its denouement.

<sup>8</sup> See the report available at [http://www.xinhuanet.com/english/2020-03/13/c\\_138875501.htm](http://www.xinhuanet.com/english/2020-03/13/c_138875501.htm), which mentions that 90% of the COVID-19 patients were treated with Chinese Traditional Medicine.

<sup>9</sup> This Ministry was established by the Government of India as recently as 2014 and is the regulatory authority for alternative medicine disciplines, such as Ayurveda, Siddha, Unani and Homeopathy.

<sup>10</sup> Multiple medical blogs as well as new reports mention this: <https://www.expresspharma.in/covid19-updates/government-to-conduct-randomised-controlled-clinical-trial-of-ashwagandha/>; [https://www.business-standard.com/article/pti-stories/covid-19-govt-to-conduct-randomised-controlled-clinical-trial-of-ashwagandha-120050701214\\_1.html](https://www.business-standard.com/article/pti-stories/covid-19-govt-to-conduct-randomised-controlled-clinical-trial-of-ashwagandha-120050701214_1.html); <https://timesofindia.indiatimes.com/life-style/health-fitness/home-remedies/covid-19-ministry-of-ayush-starts-clinical-trials-for-ashwagandha-and-4-other-ayurvedic-herbs-here-is-what-you-need-to-know/photostory/75692669.cms>; <https://www.expresspharma.in/ayush/ashwagandha-can-be-effective-preventive-drug-against-coronavirus-iit-delhi-research/>.

<sup>11</sup> <https://www.ayush.gov.in/docs/clinical-protocol-guideline.PDF>.

<sup>12</sup> <https://www.ayush.gov.in/docs/121.pdf>.

Within the space of journal publications, we have to pick the best measure to capture innovation. Academic paper writing with multiple authors (as is generally the case in most disciplines) involves joint ventures between diverse researchers, who reflect on the research problem from different perspectives. We explore the nature of the interconnections between authors, as these reflect, in a reduced form, the simultaneous adaptation and continuity in the process of knowledge transmission using the platform of academic journals. We postulate that the nature of these interconnections, as captured by the notions of network density and homophily in a research network, have the potential to capture innovation in traditional knowledge systems. Consider network density first. This measures the proportion of potential ties that are realized in an empirical network (Newman 2010). The more dense a network, the higher the number of potential ties that are actualized leading to larger flows of information. A sparse network leads to less information transmission as well as benefits and dangers of interconnections, as Hearn et al. (2003) discusses. Hence, in a densely connected network, with many cross-connections between researchers, while benefits of continuous knowledge is enhanced, the possibility of disruptive changes coming through the structure of the connections also become alive. This brings us to the issue of homophily in the research network and its relationship with adaptive innovation in networks with different densities. Homophily, which is the literal equivalent for the idiom ‘birds of a feather flock together’, in a research network reveals the extent to which ‘similar’ researchers form collaborations.

Note that most of the literature on homophily relate to a study of different attributes of researchers, such as gender (Shrum et al. 1988), race or ethnicity (Leszczensky and Pink 2015), language (Pezzuti et al. 2018) etc. and interest (Dahlander and McFarland 2013). The latter also differentiate between attribute and interest-based homophily of university researchers from their organizational foci (departments and research centers).<sup>13</sup> Note that their investigation revolves around a specific issue of tie formation versus continuations in collaborations for a particular university in the US. When it comes to traditional medicine, universities are not the optimal institutional foci for academic research, as most mainstream medical colleges teach only bio-medicine (Patwardhan and Patwardhan 2017). Traditional medicine is practiced in dedicated research centers and some specific universities, as well as by independent researchers who publish in international peer-reviewed journals such as *Journal of Ayurveda and Integrative Medicine* (J-AIM with a SCImago rank of 0.315) or *Journal of Ayurveda* (published by the National

Institute of Ayurveda, Jaipur, India) or *Ayu* (open access journal published by the Institute for Post Graduate Teaching & Research in Ayurveda, Gujarat Ayurved University, India) as well as others of less repute [see Kotecha (2015) for concerns regarding quality of publications in Ayurveda].<sup>14</sup>

For our study, an appropriate measure of homophily in publications has to capture the homogeneity in the quality of information that is exchanged through academic research collaborations, as information transmission leads to the genesis of innovative ideas in the research space. The more homogeneous this exchange, the higher will be the self-referencing character of the transmitted knowledge. The challenge here is to understand how to measure similarity. We propose two ways for discussing similarity of connections in a research network: (i) a macro measure that tests for similarity in connections in the overall network and (ii) a micro measure that explores the presence of similarity in author connections for each academic paper in the overall research network. The latter measure is a marriage between organizational foci and homophily, which Dahlander and McFarland (2013) treat as two independent conditions for studying academic collaborations. Our work is close to Dunn et al. (2012), who treat researchers in bio-medicine in terms of their relationship with the industry: either with industry affiliations or without these associations. This kind of bifurcation limits the analysis to a study of dyadic ties or collaborations only. We use a more flexible definition for affiliation by institution in order to accommodate collaborations between more than two authors. Note that there is a trade-off between the network density and homophily: knowledge perpetuation in a densely connected network requires some form of similarity among agents exchanging information such that the content of the knowledge is not subject to drastic change. This has to be the case for traditional knowledge systems that have not become extinct, but continue to co-exist with other forms of knowledge canons.

We couple our measures of homophily with a measure of quality of publications (the SCImago journal rankings). Modern publication standards, which equate publication quality using SCImago-type of journal rankings [see González-Pereira et al. (2010), Falagas et al. (2008a), cite], should yield a negative relationship between low innovation possibilities (as exhibited by high homophily) in research papers and the rank of the journal publishing such papers. Put together, our query about appropriate measures for innovation within traditional knowledge systems indicate certain patterns in the empirical research network. We expect to see that TM/CAM research networks would be marked by an integration into modern publication standards, while

<sup>13</sup> Feld (1981) define these organizational foci as institutions which may be social or legal entities around which collaborative activity is organized.

<sup>14</sup> The Ministry of AYUSH, Government of India maintains a database of journal articles published in reputed journals at <http://ayush.portal.nic.in/default.aspx>.

retaining characteristics of continuity within connections between researchers in the network. More precisely, our prediction is that research networks in Ayurveda would exhibit:

- i Conformity with modern publication standards: negative relationship of low research potential in the research network (measured using homophily) and journal publication standard (measured using SCImago rankings);
- j Higher homophily in more densely connected networks: ensuring self-preservation of knowledge in the process of transmission and exchange.

We study our predictions in two research networks specific to two specific natural herbs:<sup>15</sup> *Withania Somnifera* or Ashwagandha and *Emblica Officinalis* or Amla.<sup>16</sup> Most of the papers investigate the properties and effects of these herbs in a stand-alone fashion, with hardly any evidence of academic research on the combined effects of these two common Ayurvedic herbs. Our results corroborate the pattern we predict that perpetuates knowledge through adaptation to modern standards in publication. The more densely connected research network (*Emblica Officinalis* or Amla) shows a clear causal relationship between publication standard of a journal and the lack of homophily among author connections.

There is clear evidence of overall homophily in the research network, when we investigate connections between pairs of authors using the Q-measure of modularity. However, this macro measure does not indicate the mechanism through which homophily is likely to result in adaptive innovation in research networks. This is possible through our per-paper affiliation-based measure of homophily. The latter is our contribution to the literature on estimating measures of homophily that allows one to study supra-dyadic collaborations (research papers with more than two authors). As most papers in journals, particularly in the sciences, contain teams of more than three or four authors, our measure provides an alternative to existing measures which only study two-person collaborations.

The discussion in this paper is organized along the following lines: “[Innovation and traditional medicine: a framework for analysis](#)” section discusses the theoretical framework for understanding adaptive innovation in Ayurveda. “[Empirical methodology: measuring channels of adaptive](#)

[innovation](#)” section details the empirical methodology, including our proposed measures for capturing innovation in research networks in Ayurveda, filtered by specific herbs. “[Empirical results](#)” section discusses the data sources and the empirical results, while “[Conclusion](#)” section concludes the paper with a discussion of our findings as well as limitations in the light of the theoretical perspective we propose.

## Innovation and traditional medicine: a framework for analysis

Traditional medicine based on Ayurveda deals with naturally occurring ingredients, mostly plant-based extracts (Yuan et al. 2016; Gangadharan 2010; Samy et al. 2008). We provide a brief description of the knowledge system of Ayurveda, before investigating its positioning in modern journal publications.

### Brief discussion on Ayurveda

Ayurveda, which originated 5000 years ago in India, has adapted over the years and continues to be popularly accepted as a system for retaining health as well as curing diseases (Jaiswal and Williams 2017). This popularity was not limited to India alone in earlier times. For instance, Salema et al. (2002), in his description of colonial pharmacies in the first global age between 1400–1800 CE, describes the widespread application of Ayurvedic herbs as medicine in many parts of the world, starting with Portuguese India. He mentions that medicines originating in India, with the agency of Jesuit missionaries engaging in medicinal trade, became very important in the state-sponsored health care institutions of the Portuguese colonies around the world.<sup>17</sup> Not only medicines, research on Indian medicines providing information about (i) the medicinal properties of substances from the Indian sub-continent (ii) commercialization of these substances and (iii) market demand were published in the form of medical reports sponsored by the Portuguese Overseas Council in Lisbon. In fact, Garcia de Orta’s colloquies on the Samples and Drugs of India, published in Goa in 1563 CE, was the first printed publication on Indian plants and medicines, as mentioned in Salema et al. (2002). Garcia de Orta was a pioneer in pharmacognosy and the first European writer on Indian medicine. The outreach of this knowledge and the medicinal products covered a diverse set of regions: Macau, Timor, Mozambique, Brazil, Sao Tome and the continental Portugal (to name a few as mentioned in Salema et al. (2002)). Despite this spread, Ayurvedic texts

<sup>15</sup> After interviewing a large herb wholesaler based in Khari Baoli market (which is the largest wholesale market for herb trade in Asia), we found that these two herbs are among the highest selling ones.

<sup>16</sup> The equivalent for bio-medicine is studied in Dunn et al. (2012), where they investigate the nature of collaborations between industry- and non-industry-affiliated researchers using 22 commonly prescribed drugs.

<sup>17</sup> Native medicines from China, Brazil and Africa were part of the pantheon of colonial Portuguese medical care.

such as the Charaka Samhita (400–200 BCE), the Sushruta Samhita (1200–600 BCE), the Ashtanga Hridayam (500–600 CE), Ashtanga Sangraha (1110–1120 CE) etc., are studied by practitioners till date in the original or abridged versions.

Till 1820 CE, traditional medicine, and particularly Ayurveda, was the prevalent and respected system of medicine in countries like India and Sri Lanka. It was during the period of increasing British colonization, that is, from 1820 to 1900 CE, which saw various advances in western medicine and a consequent but slow loss of reputation of traditional medicine (Saini 2016). History has shown that the advent of Western medicine has relegated traditional systems of cure such as Ayurveda to a subaltern space (Banerjee 2009; Ravishankar and Shukla 2007; Saini 2016; Salema et al. 2002; Patwardhan 2013). The slew of standards for proving efficacy of cure, safety of cures (for example, conduct of clinical trials) coupled with recent advances in biotechnology has been at the forefront of pharmaceutical innovation in western medicine. Therefore, a natural conclusion about the decay of traditional medicine in the face of competition from its newer counterpart is attributable to its self-perpetuating standards of adaptations. As opposed to the slew of drastic innovations delivered through the institution of clinical trials and other enforceable standards in bio-medicine, Ayurveda adapted to the niche branch of ‘traditionality’ that did not incorporate similar institutions and standards.

### Existing framework to study academic collaborations and our contribution

An academic collaboration network can be modelled as a finite collection of nodes (representing individual researchers), who are connected through co-authorship edges to form a simple graph  $G$ :

$$G = \langle E, V \rangle \quad (1)$$

where  $E$  is the set of edges (co-author connections) and  $V$  is the set of nodes (authors). A few features of this definition are in order. First, an author with no connections proxies for single-authored papers. A paper with only two authors will be represented by a single edge connecting two nodes.<sup>18</sup> A drawback of this representation is that there is no direct way of capturing a paper with more than two authors. One way around this is to break up the collaborations in the paper and treat them in a binary fashion: with three authors, consider first the link between the first and the second author, then the link between the second and the third author and at last, between the first and the third author. This loses out the

flavour of the combined effect of knowledge sharing through a team of more than two people. An effective representation here requires a modification of the simple graph to a more general network structure such as a hypergraph [see Newman (2018)].

The existing literature investigating collaborations limit the discussion to dyadic connections. Our proposed micro-measure is closest to Freeman and Huang (2015), who investigate homophily<sup>19</sup> using author-ethnicity in 2.57 million scientific papers written in the US between 1985 and 2008. They find that high homophily results in a lower potential for innovation. However, in order to work with simple graphs, Freeman and Huang (2015) restrict research alliances only to the first and last authors of scientific publications assuming that they have the maximum responsibility. While this filter on the space of authors allows the overall network to retain a simple graph structure, the loss of information in the process is likely to result in an inability to answer the research question of interest. This is particularly so for us, as we assume that the composition of the research team itself reveals innovative potential.

A side issue with ethnicity as the defining characteristic for authors in the process of knowledge sharing. Traditional knowledge is likely to circulate among limited ethnicities. What might matter more are constraints imposed by the institutional affiliation of the researcher. Our measure of homophily is based on affiliations of co-authors, rather than ethnicity. Similarity in institutional affiliation of authors results in homophily, as similar resources (research budget, institutional characteristics and knowledge depositories, like access to research databases) are involved in producing research output.

Dahlander and McFarland (2013) mention five separate factors in their study of tie formation and continuation in academics: institutional foci, attribute and interest-based homophily, cumulative advantages from tie formation, triadic closure (third party reinforcement) and reinforcement of successful collaborations (tie inertia) as separate factors. However, their empirical investigation of these factors also limits itself to dyadic collaborations. In the context of citations in physics journals, Bramoullé et al. (2012) notes the presence of homophily and biases, particularly in the formation of new ties, but in a dyadic setup.

For studying integration of traditional knowledge systems with modern publication standards, there is no existing theory. We make a weak assumption about incentives that drive co-author incentives to form connections with heterogeneity in institutional affiliations:

<sup>18</sup> Figures 3 and 4 in Appendix 1 depict the Ashwagandha and Amla research networks as simple graphs.

<sup>19</sup> Similar ethnic identities of authors indicate high homophily in Freeman and Huang (2015).



**Assumption I** Successful publications in high quality journals drive collaboration incentives [tie inertia, as per Dahlander and McFarland (2013)].

Given a continuum of research journals in Ayurveda, it is possible for a researcher to choose his/her research connection to publish papers in any journal in that continuum depending on his/her research grants. The less is the institutional support as well as lower are the benefits of publishing in high quality journals, the less will be the innovative potential in the overall research network. Note here that there are no pressures or funding coming from the downstream commercial firms discovering drugs to support research incentives in this stage of research, unlike for bio-medicine [see Dunn et al. (2012) on industry-sponsored research in the latter]. It is the standards of research itself and an individual researcher's incentive constraints that determine the innovative potential of the research network.

### Empirical methodology: measuring channels of adaptive innovation

Our first measure is network density of the herb-specific research network. This measure captures the proportion of potential connections that are actually present in the graph using the simple graph representation of the Amla and Ashwagandha research networks. Network density varies between a maximum value of 1 and a minimum of 0.

Second, we work out the micro and macro measures of homophily in the two networks. The micro measure is based on the by-paper homophily index defined by Freeman and Huang (2015). For a given paper  $j$ , we define this measure  $H_j$  as the sum of the squares of the shares of each affiliation group among the authors of the paper:

$$H_j = \sum_i^N s_i^2$$

where  $N$  = number of authors;  $s_i$  = the share of the  $i$ th affiliation in the authors of paper  $j$ .

This measure is akin to the Herfindahl–Hirschman Index (HHI) used to measure concentration in markets, as mentioned by Freeman and Huang (2015). Note that Freeman and Huang (2015) define this index based on the ethnic concentration of authors writing a paper. This is straightforward, as an author can be mapped to his or her ethnicity uniquely. We do not work with author ethnicity, as we feel the nature of information flows in collaborations are better captured using the resource constraints represented by institutional affiliations. The affiliation types we consider are university departments, research centres, government-sponsored think tanks etc. There is a variety of such institutions for each author; sometimes authors have multiple affiliations. Due to this, we have to provide a tie-breaking

rule for authors with multiple affiliations. As a baseline, we assume that in cases where authors have multiple affiliations in a paper, the relevant affiliation is the:

- 1 unique affiliation of any author that is not shared with any of the other author as the relevant affiliation;
- 2 if the earlier option is not possible (that is, there exists no unique affiliation for the author), then we select the first of the listed affiliations of the author.

This tie-breaker assumption is, of course, a bit arbitrary. In a later section, we conduct a robustness check of our results by changing this assumption to see if the regression results hold. In either case, the least homophily is exhibited when all the authors have different institutional affiliations whereas the highest degree of homophily occurs when all the authors belong to the same department in the same institution. If all of the authors on a paper have the same affiliation (i.e., they belong to the same department in an institution), then  $H_j$  equals 1.0, which is the maximum value of the homophily measure. If the paper has authors of different affiliations, then  $H_j$  takes different discrete values for papers depending on the number of affiliations and number of authors on a paper.<sup>20</sup>

Next, we follow up the by-paper homophily measure with the homophily or assortative mixing in the *overall herb networks* of Amla and Ashwagandha. In this more macro-measure, we work with a simple graph characterization and therefore, and use coarser categories for affiliation. Here,

<sup>20</sup> We illustrate the calculation of  $H_j$  for the general case first and then for cases 1. and 2. mentioned above. For the general case: consider the paper titled 'Clinical efficacy of Amalaki Rasayana in the management of Pandu (Iron deficiency anemia)' co-authored by S. Layeeq (Department of Panchakarma, Uttarakhand Ayurved University) and A.B. Thakar (Department of Panchakarma, Gujarat Ayurved University) in the Amla Research Network. Here,  $H_j$  is the sum of  $(1/2)^2 + (1/2)^2$  which is equal to 1/2 since  $s_i$  for each affiliation is 0.5. Now, in the case of tie-breaker 1., for the paper from the Ashwagandha research network titled 'Antihyperalgesic effects of Ashwagandha (Withania somnifera root extract) in rat models of postoperative and neuropathic pain', two out of the four authors have multiple affiliations. All the authors are affiliated to Korea Food Research Institute, but two are additionally affiliated to the Korea University of Science and Technology. Thus, we consider the unique affiliation of the last two authors and  $H_j$  is calculated as the sum of  $(2/4)^2 + (2/4)^2$  and is equal to 0.5. In the case of tie-breaker 2., for the paper titled 'Effects of Withania somnifera and Tinospora cordifolia extracts on the side population phenotype of human epithelial cancer cells: toward targeting multi-drug resistance in cancer' has six authors: N. Maliyakkal, A. Appadath Beeran, S.A. Balaji, N. Udupa, S. Ranganath Pai, A. Rangarajan. The first author is affiliated to the Indian Institute of Science (IISc) as well as Manipal University, the second, fourth and fifth authors are affiliated to Manipal University and the third and sixth authors are affiliated to IISc. Here, since there are no unique affiliations, we take that the first author is affiliated to IISc (first of the listed affiliations). Thus, we calculate  $H_j$  as the sum of  $(3/6)^2 + (3/6)^2$  which is equal to 0.5.

authors are divided into four categories: authors whose institutions are based in India, Sri Lanka, rest of the world (not India or Sri Lanka) and multiple institution/country affiliations. The separate categories for India and Sri Lanka is due to the fact that these countries have a cultural tradition of Ayurveda historically. We calculate Newman's specification [see Newman (2010)] of the measure of modularity,  $Q$ , based on affiliations to ascertain the presence of homophily or assortative mixing in our networks as follows:

$$Q = \frac{1}{2m} \sum_j \sum_i \left( a_{ij} - \frac{k_i k_j}{2m} \right) * \delta(c_i, c_j) \quad (2)$$

Here,  $a_{ij}$  = element of the adjacency matrix between nodes  $i$  and  $j$ ;  $k_i$  = degree of node (author)  $i$ , i.e., the number of authors that are connected to node  $i$ ;  $c_i$  = type of node  $i$ , i.e., whether the node  $i$  has an Indian, Sri Lankan, foreign (other than Indian or Sri Lankan) institution affiliation or multiple affiliations;  $m$  = total no. of edges in the network;  $\delta$  = Kronecker delta which is 1 when  $c_i = c_j$ , i.e., when nodes  $i$  and  $j$  are of the same type.

This  $Q$  measure has the advantage of comparing the presence of homophily relative to a counterfactual of what kind of connections would be present if, unlike our *Assumption 1*, authors randomly chose co-authors for writing research papers. The deliberate strategic choice in collaborative connections, assuming that it increases the chance of publishing in high quality journals, is captured through this measure through its two terms: the first term in the formula of  $Q$  represents the actual level of assortative mixing in the empirical network and the second term is the extent of this mixing that we are likely to see if all the links in the network were created randomly. A positive value of  $Q$  indicates significant assortative mixing and hence homophily in the network, whereas a near-zero value of  $Q$  is indicative of very little homophily in the network.

The publication standard of academic journals, whose relationship we study next in relation to homophily, is measured using the SCImago rank.<sup>21</sup> Our assumption is that a high SCImago rank is indicative of high quality of innovation. We use the SCImago ranking since it based on the idea that 'not all citations are equal'. The alternative measure, Average Impact Factor is, in fact, highly correlated with the average SCImago rank.<sup>22</sup> The causal relationship we test predicts the manner in which the SCImago rank of a journal (dependent variable) varies with our micro measure

of homophily (independent variable) with additional controls. For this purpose, we conduct a quantile or percentile regression, since the distribution of our dependent variable (SCImago ranking of journals) is skewed and not normally distributed. Quantile regression is based on the estimation of conditional quantile functions as against the classical linear regression which is based on minimizing sums of squared residuals. Linear regression helps in estimating models for conditional means whereas quantile regression estimates models for the conditional median as well as other conditional quantiles. Further, the quantile regression treats outliers and non-normal errors more robustly than the Ordinary Least Squares (OLS) regression. We contrast our results against the standard OLS regression results. We expect that less 'homophilous' are author affiliations in a paper, the higher will be the innovative potential of the paper. The likelihood of publication in a higher ranked journal therefore, higher will be the SCImago ranking. Hence, we expect a negative relationship between  $H_j$  and average SCImago ranking.

## Empirical results

### Description of data

We use data on research papers from PubMed Database, which is maintained by the US National library of Medicine and National Institutes of Health, for a five year period (30 July 2013 to 30 July 2018). It contains more than 28 million citations for biomedical literature from MEDLINE, life science journals, and online books. Search string matters for all bibliometric research. We found that research papers which appear with the string search 'Withania Somnifera + Ayurveda' are contained in 'Ashwagandha + Ayurveda' but not vice versa. Hence, we used the former search string. For Amla, we combined the searches 'Amla + Ayurveda' and 'Embllica Officinalis + Ayurveda', that is for both traditional/local name and scientific name, because the union set represents more papers than individual searches, and the brief overview of abstract also shows that the herb has been used in the analysis for the paper. We list information on articles, authors, and the country of institution of the author as well as authors' institutional affiliations. Note that if the papers are not available online, we mark the authors' affiliation as not available. Also, when an author has co-authored more than one paper, where for one paper the affiliation is given while for others it is not mentioned, then we take the affiliation which has been mentioned as relevant.

<sup>21</sup> The official website (<https://www.scimagojr.com/>) which generates SCImago journal ranking (SJR) describes SJR to be 'based on the transfer of prestige from a journal to another one; such prestige is transferred through the references that a journal do to the rest of the journals and to itself.'

<sup>22</sup> This is in line with González-Pereira et al. (2010)'s findings.

**Table 1** Summary statistics—Ashwagandha network. *Source:* Authors' own calculations

Variable	Obs.	Mean	Median	SD	Min	Max
Average SJR	74	0.970	0.878	0.635	0.248	3.308
$H_j$	82	0.618	0.503	0.290	0.185	1
Degree of corresponding author	81	5.272	4.000	5.162	1	25
Log (No. of references)	79	3.638	3.761	0.616	2.079	5.204

**Table 2** Summary statistics—Amla network. *Source:* Authors' own calculations

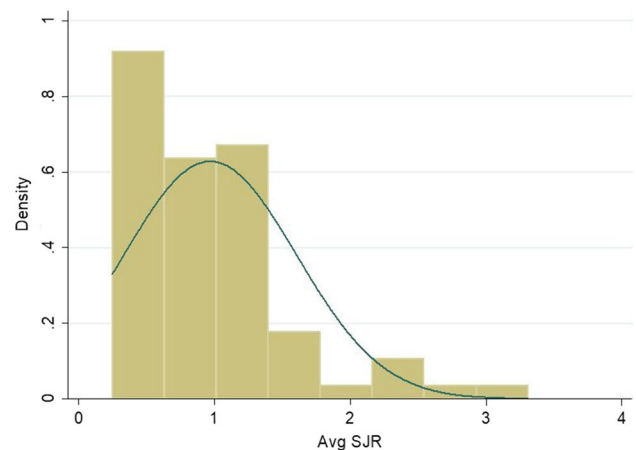
Variable	Obs.	Mean	Median	SD	Min	Max
Average SJR	38	0.758	0.672	0.469	0.280	2.191
$H_j$	44	0.583	0.538	0.254	0.139	1
Degree of corresponding author	44	4.795	3.000	5.224	1	25
Log (No. of references)	44	3.614	3.676	0.656	2.079	5.710

## Results: descriptive statistics

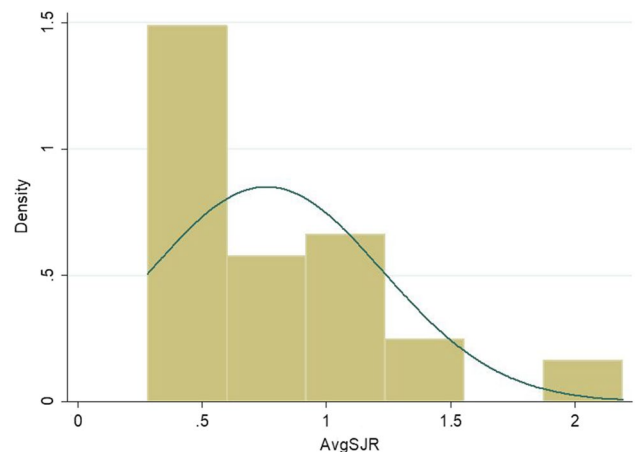
The number of observations in the Ashwagandha network is almost twice that of the Amla network, though on an average, an author in each of the networks has the same degree. The graph density of the Amla research network is higher (it is 0.035) compared to the Ashwagandha network (for which graph density is 0.016).<sup>23</sup> These figures for graph density are extremely low, particularly in comparison with a complete graph (in which every pair of nodes is connected by a unique edge) with density equal to 1. However, relative to the Amla network, Ashwagandha has more research papers written over the five year period taken in consideration. Continuity of knowledge, when many authors are involved in the overall research network, is ensured by:

- 1 Similar per-paper homophily among authors by affiliation ( $H_j$ ) in the less dense Ashwagandha network (average homophily score is 0.618) compared to the more densely connected Amla network (average homophily score is 0.583).
- 2 Higher variation in the quality of journals in the Ashwagandha network (measured by the Average SJR variable). Its standard deviation in the Ashwagandha network is relatively high at 0.635 compared to 0.469 for the Amla network.
- 3 Higher per-paper homophily ( $H_j$ ) in achieving higher quality publications; the value of the average SCImago Journal Rank (SJR) is significantly higher at 0.97 for the Ashwagandha network compared to 0.76 for the Amla network. This implies compliance of research alliances

<sup>23</sup> Refer to Tables 1 and 2 for the descriptive statistics of these research networks.



**Fig. 1** Legend: (X-axis): Avg SJR is the average SCImago ranking of the journal ranging from 0.25 to 3.5; (Y-axis): the density of journals for a particular Avg SJR. *Source:* Authors' own creation



**Fig. 2** Legend: (X-axis): Avg SJR is the average SCImago ranking of the journal ranging from 0.25 to 2.5; (Y-axis): the density of journals for a particular Avg SJR. *Source:* Authors' own creation



to modern standards of publication implicit in *Assumption 1*.

Note that the average SCImago rank (Average SJR), as shown in the histograms in Figs. 1 and 2 respectively for Ashwagandha and Amla, are significantly skewed. Most of the journal papers are clustered in intervals, as the bars of the histograms show in these figures.<sup>24</sup> Not only is there an interval-specific clustering, the bulk of journals in both the networks have a low SCImago rank. Most of our observations (the highest density of journals) are bunched towards very low values on the X-axis, much below the mean Average SJR. This can also be read off from the continuous line fitted to the histograms. Though both the histograms look similar, the fitted line clearly shows that almost all the papers in the Amla network are below an average rank of 2, whereas in the Ashwagandha network, there is a small presence (less than 50%) of papers above the SCImago rank of 2. This reveals that the overall quality of journals and therefore, papers and their innovative potential in the Amla network is worse than in the Ashwagandha network. This is, of course, beholden to our assumptions about inferences of innovative potential and high quality in papers as reflected by the average SCImago (SJR) ranks.

We point out here that the Average SJR ranking is not a paper-level metric, that is, it will only change when the journal where the paper is published changes. We have papers that are published in the same journal and therefore, we have repeat values of the ranking scores. What we find is that for both networks, the median is less than the mean for all values of average SCImago ranks and that low quality publications outnumber higher quality ones in our data.

### Alternative measure of homophily: modularity of the entire network

As mentioned earlier, there are multiple ways to measure homophily. Other than our per-paper affiliation-based measure, we can comment on the extent of assortative mixing or modularity in the entire network (see the definition in “[Empirical methodology: measuring channels of adaptive innovation](#)” section). We find existence of assortative mixing or homophily in the overall research networks we study, as the value of  $Q$  (0.286 for the Amla network and 0.425 for the Ashwagandha network respectively) is higher than zero. The  $Q$  measure shows a higher overall homophily in the Ashwagandha network relative to the Amla one. The simple graphs in Figs. 3 and 4 in Appendix 1 show the connections in these

<sup>24</sup> This interval-specific clustering of the Average SJR is the reason we represent these figures, therefore, by using the histogram bar graph rather than a line graph. We thank an anonymous referee for helping us clarify this representation.

networks dyadically. These graphs reveal an empirical regularity seen in most modern publication networks: authors in disciplines like traditional medicine mostly work in small connected sub-graphs (indicating that collaborations are deliberate and non-random [see Newman (2001) regarding limited number of collaborators in theoretical disciplines like high energy theory]). Indian authors rarely form collaborations with Sri Lankan and other foreign authors. The presence of the latter type of authors is in predominance in the Ashwagandha network than in the Amla one: it is interesting that despite Ayurveda’s historical origins in India, foreign institutions outside the South Asian region engage with the discipline. However, the nature of these academic endeavours is limited within their own cliques, giving rise to a higher  $Q$  measure for the Ashwagandha network than the Amla network.<sup>25</sup>

Now, the two measures of homophily are not directly comparable, as their objectives are different. The  $Q$ -measure works out whether connections formed in the network are strategic or random in the network as a whole (the first term in the formula for  $Q$  works out the extent of strategic connections in the network relative to the second term capturing random connections). The micro measure works out homophily at the level of individual research papers in the network whereas for the calculation of the  $Q$ -measure, authors are classified in terms of four affiliations (Indian, Sri Lankan, Others and Multiple affiliations). A positive value of  $Q$  shows that research links in the networks we study are made strategically, which supports our hypothesis that adaptive innovation works out through some form of homophily in the network. The last point that deserves a further exploration is the precise relationship between journal quality and homophily, which we work out in the next section.

### Results for affiliation-based homophily and SCImago ranking

Recall that the SCImago rankings were highly skewed in both the networks. Hence, we investigate the effect of homophily, after controlling for other network-specific features, on the SCImago ranking of journals in each network using a quantile regression. The dependent variable is the average SCImago journal ranking in the network and the independent regressor of interest is the homophily index. We control for the degree of corresponding author in the respective network and total number of references<sup>26</sup>

<sup>25</sup> We thank an anonymous referee for helping us clarify this discussion regarding the simple graph depiction.

<sup>26</sup> The number of cited references is a standard variable used in bibliometric studies conducted in the field of information sciences. An example of such a study is Bornmann and Mutz (2015) which uses the number of cited references to examine the growth in science literature since the mid-1600s.

**Table 3** OLS and quantile regression results for average Scimago ranking: Amla network. *Source:* Authors' own compilation from respective company websites'

Variable	OLS	Percentile for quantile coefficient						
		0.25	0.50	0.55	0.60	0.65	0.70	0.75
$H_j$	-0.604**	-0.352	-0.543	-0.746**	-0.752***	-0.792***	-0.648***	-0.993
SE	0.299	0.300	0.401	0.363	0.407	0.398	0.335	0.762
Degree of corresponding author	-0.004	-0.011	0.007	0.000	-0.001	-0.007	-0.007	-0.016
SE	0.014	0.014	0.019	0.017	0.019	0.019	0.016	0.036
Log (No. of references)	0.440*	0.216***	0.334*	0.397*	0.406**	0.469*	0.469*	0.550***
SE	0.114	0.115	0.154	0.139	0.156	0.153	0.128	0.292
Pseudo- $R^2$ ( $R^2$ for OLS)	0.327	0.147	0.233	0.245	0.257	0.25	0.258	0.247

\*Significant at 1% level

\*\*Significant at 5% level

\*\*\*Significant at 10% level

and contrast our results with the Ordinary Least Squares (OLS) regression to see the effect of the skewness on the causal relationship between journal quality ranking and the independent variables. If skewness matters in the regression, then the OLS regression (which predicts the effect of the independent regressor on the mean value of the independent variable, in the presence of other controls) would show a different pattern compared to the effect on the other quantiles. Other than the 25th, the 50th (the median) and the 75th quantile, we consider a few other percentiles of the independent variable to depict the non-linearity. We present in table 3 the results using  $H_j$ , which is our micro measure of homophily based on Freeman and Huang (2015)'s methodology.

We find that effect of homophily ( $H_j$ ) on the Average SCImago ranking works out differently for (i) different techniques of estimation techniques (OLS as opposed to quantile regression) and (ii) different research networks, Ashwagandha and Amla.

The goodness-of-fit measure for Amla (as captured by the pseudo- $R^2$  values) are much lower as compared to those for the Ashwagandha network (see Appendix 2 for the results for the Ashwagandha network). This could presumably be because of the relatively lower number of observations in the Amla network. Additionally, the homophily measure ( $H_j$ ) significantly lowers the quality of journals for the OLS regression and the 55th, 60th, 65th and 70th percentiles. Hence, the results of the OLS average out the effect of homophily on quality of publications and the percentiles depict a comparatively accurate picture. For the Ashwagandha network, we find that  $H_j$  does not significantly impact the average SCImago ranking in the OLS regression as well as the different quantile regressions (refer to Table 5 in Appendix 2). The quantile regression, however, shows a non-linear impact on the different

quantiles of the independent variable attributable to  $H_j$ . For the 55th (or the 60th) percentile value of the independent variable, if  $H_j$  increases by one unit the average SJR decreases by 0.746 (or by 0.752). These results hold at 10% level of significance. However, at the 75th quantile, the effect of  $H_j$  is no longer significant.

### Robustness check: changing the tie-breaker assumption for $H_j$

In "Empirical methodology: measuring channels of adaptive innovation" section, we defined the affiliation-based micro homophily measure with two caveats for the case when authors of papers are affiliated to more than one department/institution. To check whether our results of the previous section hold, we change the two of our earlier assumptions regarding the tie-breaker on papers with multiple author affiliations as follows:

- i. instead of the unique affiliation for the author with multiple affiliations, we use the most common affiliation (that is, affiliation that is shared by at least one other co-author);
- ii. when there exists no common affiliation, then we take the last among the listed affiliations of the author with multiple affiliations, instead of the first one.

We now redefine  $H_j$  as  $H_R$  and replicate our OLS and quantile regressions. The results for the Amla network are shown in Table 4.

Comparing Table 4 with Table 3, we find that our results have not changed in any significant way. Thus, we conclude that results using our micro-measure of homophily are robust to changes in the definition of  $H_j$ .

**Table 4** OLS and quantile regression results for average Scimago ranking: Amla network. *Source:* Authors' own compilation from respective company websites'

Variable	OLS	Percentile for quantile coefficient						
		0.25	0.50	0.55	0.60	0.65	0.70	0.75
$H_R$	-0.724**	-0.352	-0.642	-0.790***	-0.812**	-0.994**	-0.962**	-0.993
SE	0.316	0.268	0.441	0.397	0.389	0.396	0.370	0.834
Degree of corresponding author	-0.006	-0.011	0.003	-0.001	-0.003	-0.010	-0.014	-0.016
SE	0.014	0.012	0.020	0.018	0.017	0.018	0.016	0.037
Log (No. of references)	0.463*	0.216***	0.368**	0.409*	0.427*	0.490*	0.538*	0.550***
SE	0.115	0.097	0.160	0.144	0.141	0.144	0.134	0.303
Pseudo- $R^2$ ( $R^2$ for OLS)	0.347	0.149	0.238	0.247	0.253	0.258	0.257	0.257

\*Significant at 1% level

\*\*Significant at 5% level

\*\*\*Significant at 10% level

## Conclusion

Our paper provides a method to understand the nature of innovation (we term this adaptive innovation) that allows a canon of knowledge to not become extinct while ensuring continuity in content.<sup>27</sup>

Being traditional does not indicate rigidity. Nijar (2013) studies customary law and its relationship with traditional knowledge and he observes that these systems are dynamic and exhibit flexibility through 'a process of natural indigenous resources management that embodies *adaptive responses*'. The presence of these adaptive responses allow for a specific type of dynamic pattern or innovation. Hearn et al. (2003) discusses the role that innovation has in complex systems, which, we believe, carries over to traditional knowledge systems. Their claim that

It is, paradoxically, also true that innovation also requires some stability and security in the form of such things as organisational structure, discipline and focus.

makes our research quest less blunt than *whether innovation is possible within stable traditional systems of knowledge to a more nuanced search for how to understand the process of innovation in such systems and measure them*. Of the possible patterns that a complex system can exhibit, Hearn et al. (2003) distinguishes four:

- i. self-referencing: a condition that leads to perpetuation and continuity in knowledge.
- ii. self-organization: which arises from exogenous changes resulting in adaptations to the existing body of knowledge.

- iii. self-transformation: that leads to drastic Schumpeterian upheavals in established canons of knowledge, mostly through endogenous changes from within the system.
- iv. extinction: changes that result in complete demise of a system.

Of these four conditions, traditional medical systems display self-referencing, as processes and institutions that deal with these have resulted in preservation of knowledge for thousands of years. The fact that the last condition of extinction is not the case with traditional medicine, it must be the case that the institutional structures and interactions among practitioners over the years have adapted themselves [self-organization as per Hearn et al. (2003)], leading to self-perpetuation. The continuity of the structure of knowledge in disciplines like Ayurveda also imply that Schumpeterian innovations or drastic innovation, which would destroy channels for continuing embedded knowledge, are absent. This clearly shows that innovation is not antithetical to traditional knowledge systems, just that the processes of adaptation and change result in perpetuation in knowledge. While we do not expect to see drastic innovation that marks modern bio-medicine, a detailed study of these knowledge systems should reveal very nuanced forms of self-perpetuating adaptations.

In the specific context of herb-specific academic paper networks in Ayurveda, we find that a lower affiliation-based homophily is causally linked with higher publication ranking, as measured by the SCImago ranks of journals publishing these papers. However, more diverse collaborations with low homophily are costly, as per our theory and the contentions of Dahlander and McFarland (2013). Simultaneously, low homophily breeds the possibility of content dilution in the knowledge system. Therefore, as a natural response to retaining ties with low collaboration cost [as Dahlander and McFarland (2013) would argue], the research networks we

<sup>27</sup> Measuring innovation is not easy in traditional knowledge systems, as most standard metrics like patents are not valid. Ayurveda is a classic example of a traditional body of medical knowledge, which has continued with only marginal change in its character in some countries of South Asia, particularly India and Sri Lanka.

study exhibit high levels of homophily, be it through the lens of assortative mixing or affiliation-based homophily measures. A resultant effect is that these ties allow continuity in the content and structure of knowledge itself, despite an adaptation to modern publication standards. This becomes an adaptation strategy for a traditional knowledge system that continues to persist at present with the retention of the basic structure of knowledge.

Our findings regarding institution-based homophily also resonate with the finding of Dunn et al. (2012) that there is homophily among industry-affiliated researchers in bio-medicine. In comparison with non-industry-affiliated researchers, those with industry links publish more often and more so, with each other. This kind of perpetuation of connections seems to be the commonality of research themes that is necessary for research that has similar type of pharmaceutical industry-based funding. Our result regarding similarity in institutional affiliations in publications, despite lowering of the quality of publications, indicates not only the ease of finding collaborators [as mentioned by Dahlander and McFarland (2013)], but also the commonality of content that helps perpetuate knowledge. However, they find a continuation from the industry to research through collaboration links between industry-linked authors. In sharp contrast, the absence of institutions like clinical trials prevent any meaningful incentives for the drug manufacturing industry to invest in the research segment in Ayurveda.

Note one problem with the publications space is its survival bias: we can only study successful collaboration, not the unsuccessful ones. This is a drawback of all studies that investigate collaborations through the space of academic publications [see Dahlander and McFarland (2013)]. A different issue remains about our method of analysis: are research publications the appropriate space to look for adaptive innovation in traditional knowledge systems? Undoubtedly, we use a modern standard and retrofit it to understand collaborative processes in traditional knowledge systems. These disciplines, which have survived many years of transitions are often best seen as lived traditions [see Robbins and Dewar (2011) for traditional indigenous medicine in the Americas]. Most practitioners of Ayurveda still refer to the classic texts of Charaka Samhita as relevant texts in their practice.<sup>28</sup>

In sum, if traditional medicine adapts itself to modern publication standards, the path it takes is no different from other disciplines that publish in such platforms, such the

existence of a small cluster of connected authors in an otherwise sparsely connected network (see Figs. 3 and 4 in Appendix 1.<sup>29</sup>) The modalities of the publication platform determine the quality of connections to a large extent when traditional knowledge finds these outlets for knowledge dissemination. What remains suspect is the overall engagement of traditional medicine in particular and traditional knowledge, in general, with modern publication standards. Recent initiatives by the Ministry of AYUSH, Government of India, have resulted in the creation of a repository of modern journals with publications in Ayurveda, just as PubMed is an international collection of such publications. However, the researcher and the practitioner is unlikely to be the same agent, as our survey of 2018 found. The rise of a culture of knowledge dissemination through journals gives rise to the possibility of a disconnect in traditional disciplines: those who publish in journals and those who practice the discipline. What the two sets of individuals believe about innovation within the discipline are likely to be very different. We have limited our analysis to the space of academic journals in this paper. The overall engagement of Ayurveda with modern publication standards and what it does to the discipline is part of our future research agenda and has not been addressed in this paper.

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## Compliance with ethical standards

**Ethical statement** This article does not contain any studies with human participants or animals performed by any of the authors.

**Conflict of interest** Debdatta Saha has no conflict of interest. T. M. Vasuprada has no conflict of interest.

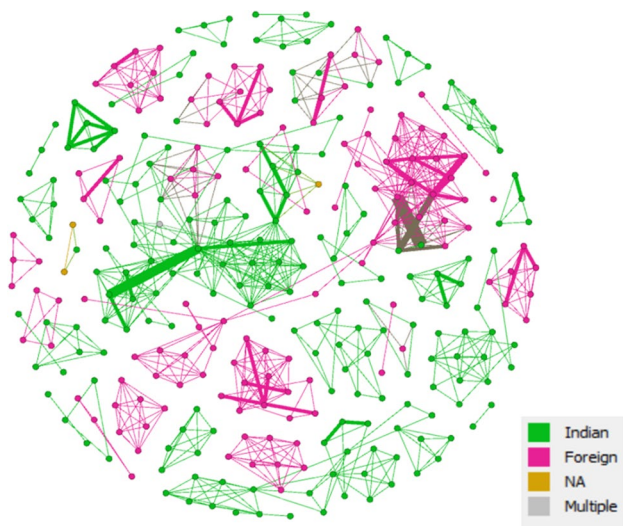
## Appendix 1: Ashwagandha and Amla Research Network

See Figs. 3 and 4.

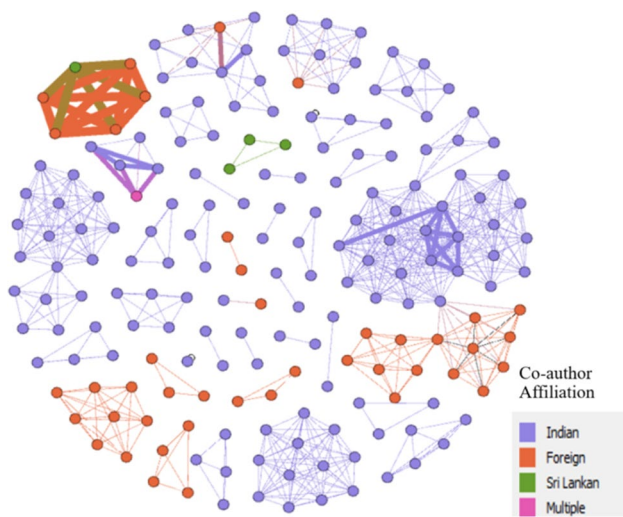
<sup>28</sup> In 2018, we conducted a survey among of Ayurveda practitioners in Delhi and Kerala to understand the nature of innovation within the discipline. From the 32 relevant responses, we found that majority refer to the classic texts as the relevant source of knowledge. There was a mention of research conducted by dedicated institutions for Ayurveda, but the research output is not regularly used in our sample.

<sup>29</sup> As we mentioned earlier, Dunn et al. (2012) mentions dense clustering of authors with industry linkages connect more often with each other than with other types of authors in bio-medicine.





**Fig. 3** Legend: Author nodes with affiliations in Indian institutions are in green, foreign institutions are in pink, ochre yellow color nodes are not determined uniquely whereas limited gray node authors have multiple affiliations. *Source:* Authors' own creation using the software Gephi version 9.0



**Fig. 4** Legend: Author nodes with affiliations in Indian institutions are colored light purple, foreign institutions are in orange, green color nodes are Sri Lankan whereas limited pink node authors have multiple affiliations. *Source:* Authors' own creation using the software Gephi version 9.0

## Appendix 2: OLS and Quantile Regressions for the Ashwagandha Network

See Table 5.

**Table 5** OLS and quantile regression results for average Scimago ranking: Ashwagandha network. *Source:* Authors' own compilation from respective company websites'

Variable	OLS	Percentile for quantile coefficient		
		0.25	0.50	0.75
$H_j$	0.162	0.242	0.183	0.248
SE	0.193	0.210	0.215	0.410
Degree of corresponding author	0.041*	0.034*	0.021***	0.080*
SE	0.011	0.012	0.012	0.023
Log (No. of references)	0.634*	0.447*	0.558*	0.565**
SE	0.102	0.111	0.114	0.217
Pseudo- $R^2$ ( $R^2$ for OLS)	0.496	0.284	0.341	0.301

\*Significant at 1% level  
 \*\*Significant at 5% level,  
 \*\*\*Significant at 10% level

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