Triple Helix indicators as an emergent area of enquiry – a bibliometric perspective

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Abstract

This contribution explores how work on Triple Helix (TH) indicators has evolved. Over the past 15 years a body of literature has emerged that brings together a variety of approaches to capture, map or measure the dynamics of TH relationships. We apply bibliographic coupling and co-citation in combination with content analysis to develop a better understanding of this literature. We identify several clusters that can be aggregated to two broad streams of work – one 'neo-evolutionary', the other 'neo-institutional' in nature. We make this observation both for bibliographic coupling and co-citation analyses which we take as indication of an emerging differentiation of the field. Our content analysis underlines this observation about the 'two faces' of the Triple Helix. We conclude this paper with a discussion of future opportunities for research. We see great potential in developing the application side of TH indicators.

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Introduction

From an initially contentious and critically reviewed notion (Shinn 2002), the Triple Helix (TH) framework has established itself as a core concept in the discourse of university-industry-government relations and beyond (e.g. Leydesdorff *in press*). The literature on the Triple Helix has grown substantially over the past ten years. If one looks at the *Social Sciences Citation Index (SSCI)* alone, one can track close to 300 papers on the Triple Helix (Meyer 2012). Nevertheless, this is likely an under-estimation of all work related to the TH. Our contribution is concerned with a particular subset of Triple Helix scholarship – namely work on science, technology and innovation indicators that pertain to university-industry-government relations and their associated functions. Just as with the field at large, the literature on Triple Helix indicators has grown rapidly. More than 100 papers in the *SSCI* can be related to TH indicators of university-industry-government relations and it is fair to say that indicators have become a key aspect of work on university-industry-government relations (Meyer 2012).

Apart from a number of editorials, there are relatively few contributions that present an overview of TH scholarship indicators. Our contribution aims to help close this gap by offering a bibliometric perspective. Specifically, we seek to (1) develop a better understanding of the role of research on indicators within the Triple Helix context; (2) explore whether and, if so, how one can differentiate between different research approaches in the TH indicators; and (3) examine the 'knowledge base' of TH indicators, i.e. which sources TH indicators work cities and how they are related to another. We conclude this paper with a discussion about how work on indicators can further the development of TH frameworks and practice.

Context

The Triple Helix Framework: Its Origin and Evolution

Work on TH indicators must be viewed within the context of the TH framework. The "Triple Helix" is a multi-structural, multi-functional and non-linear model of innovation, initially developed and pioneered by Loet Leydesdorff and Henry Etzkowitz. In their first joint publication, they argue whether (1) to include changes in knowledge production and distribution in the explanations of innovation, and thereby economic and social development of knowledge-based economies and (2) to explain changes in the knowledge base in terms of transformations in the functions of universities, industry, governments and in the relations among them (Leydesdorff and Etzkowitz 1996). In the words of Leydesdorff and Etzkowitz, the core of the "Triple Helix" is that "university-industry-government network relations are the key to knowledge-based economic development in a broad range of post laissez-faire capitalist and post-socialist societies" (Leydesdorff and Etzkowitz 2001, p.17) and "that the university can play an enhanced role in innovation in increasingly knowledge-based societies" (Etzkowitz and Leydesdorff 2000; Etzkowitz 2003).

The early writings on TH debated how to conceptualise the three elements of the TH model (e.g. Leydesdorff and Etzkowitz (1998) referred to them as institutions and communication systems). The understanding that emerged is that the three institutional spheres fulfil their traditional functions but also assume the role of others (e.g. Etzkowitz and Leydesdorff 2000, Leydesdorff and Etzkowitz 2001, Etzkowitz 2003). For instance, in addition to their traditional roles, universities start new ventures, firms provide higher education-level training for their employees and governments act as venture capitalists. These changes in the function of each institutional sphere are brought about through evolving relations among them and vice-versa. The relations of university, industry, and government become closer as communication networks and hybrid organisations emerge between them. Their relations can be characterised as simultaneously competitive and cooperative. Moreover, the university is recognised as just as equally important a player as industry and government in the innovation process.

Early TH works differentiate the TH model from other conceptual models of innovation, such as evolutionary economics (Leydesdorff and Etzkowitz 1996), Mode 2 and national/regional systems of innovation (Leydesdorff

and Etzkowitz 1998; Etzkowitz and Leydesdorff 2000; Etzkowitz 2003). It is argued that the TH model has a greater capacity to explain changes in innovation systems than the exiting frameworks. The TH idea was introduced into the language borrowing concepts from evolutionary economics (as illustrated by references to evolutionary theory, lock-in of co-evolving helices and interactions reshaping technological trajectories) but quickly a distinctive terminology was developed (e.g. "entrepreneurial universities", "tri-lateral networks", "enhancing existing roles", "institutions taking the role of another"). Early TH works also aimed to legitimise and popularise the model by providing empirical examples of changes in university, industry and government, and in relations among them in developed and developing countries and by highlighting the policy relevance of the TH model and its uptake by government agencies (Leydesdorff and Etzkowitz 1998).

The significance of the TH model can be illustrated by the amount of research that it inspired in the last few years. The model calls for an analysis of the forces driving changes in the configurations of university-industry-government relations as well as their consequences. It also recognises that the stages in the emergence of TH configurations and entrepreneurial universities may be different across countries with different economic systems (Etzkowitz 2003) and that trilateral dynamics can be analysed at regional, national and supranational levels. A number of contributions have examined these aspects of the TH model in different empirical settings (e.g. Lengyel and Leydesdorff, 2011) and some of them were published together with more theoretical pieces in a number of special issues dedicated to the TH, including issues in Science and Public Policy (1996, 1998), Research Policy (2000, 2006), and Scientometrics (2003, 2007). Furthermore, the methods, claims and concepts of the TH perspective and its connected empirical, conceptual and policy agenda have also attracted critical examinations by a number of scholars (e.g. Shinn, 2002).

Recent work has focused on extending the TH model to more than three helices but also on differentiating between the two underlying models and their graphical representations proposed by Etzkowitz and Leydesdorff, which has provided the heuristics to the TH model. Some extensions by proponents of a 'Mode 3' of knowledge production propose a fourth helix to bring 'society' or 'the public' - viewed in terms of media-based and culture-based public and civil society - back into the model, but also a fifth helix to represent the natural environment (e.g. Carayannis and Campbell, 2012).

While at the beginning of the debate the focus was on differentiating the newly emerging TH concept from other notions and contexts, the Triple Helix literature has more recently undergone a process of differentiation in which a tension between two initially underlying models is becoming more apparent. On the one hand, there is Etzkowitz's 'neo-institutional' approach, which focuses on networking and exchanges between different organisational spheres of the Triple Helix while, on the other, Leydesdorff's (in press) model is concerned with capturing the 'neo-evolutionary' mechanisms of exchanges between typically three functions - wealth creation, knowledge production, and normative control. In the following we will also explore the extent to which these developments are reflected in work on indicators.

Methodology & Data Collection

We collected data from Thomson-Reuters *Social Sciences Citation Index*. We readily acknowledge that a wide range of databases has become available, including for example *Scopus* or even *GoogleScholar*, that could also be used to study scholarship on *Triple Helix* and *Triple Helix indicators*. We contend that the *Social Science Citation Index* is a reasonable data source as our focus is on the indicators subset rather than the Triple Helix literature at large. The SSCI offers a comparatively good coverage of journals in this specific area.

Searching for *'Triple Helix'* and *'university-industry-government relations'* covering title, abstract and key word sections we identified a total of 277 papers (articles, notes, reviews and letters). We combined the above search with terms such as *indicator** OR *metric** or *scientometric** or *bibliometric** or *informetric** or *measure** to identify papers covering TH indicators – covering at the time a total of 109 papers and 5244 references.

We used the Bibexcel (2008) software package to process, clean and standardise the dataset (see also Persson et al. (2009). We applied both bibliographic coupling (Kessler 1964) and co-citation analysis (Small 1973;

Marshakova 1973) to this dataset. Bibliographic coupling relates the *citing* papers of a dataset to each other on the basis of the references they share while co-citation analysis focuses on the references (the *cited* documents) relating them to each other on the basis of being cited together by papers in the dataset (see e.g. Glänzel 2003). Both analyses were carried out at the level of individual publications,[1] applying reasonable thresholds in both instances.

We applied both approaches because of their inherent complementarity. Bibliographic coupling is particularly useful because it also covers the most recent papers in a database and it is not only based on cited documents (Glänzel 2003). This allows us to identify recent strands of the literature and also explore how they are related to each other. Co-citation analysis enables us to study the 'knowledge base' of the TH indicators papers by exploring different research strands in the references they cite. This allows us to get a better understanding of the role publications also outside the field have for scholarship on TH indicators.

To identify different streams of interrelated works, we performed cluster analyses on both coupling and co-citation datasets applying Persson's (1994) clustering algorithm. The chosen non-hierarchical, single-link clustering approach is one of the most common techniques in our context of study. As Persson (1994) elaborates, the "idea is that the scientific literature is connected into a network within which documents are linked to each other with various degrees of strength. One single-link method works as a pair of scissors cutting off the weakest links. In this manner, clusters varying in size are produced" (Persson 1994, p. 32).

As in many other studies examining scholarly collaboration (Luukkonen et al. 1993; Leydesdorff 2008), the Jaccard index was used for normalisation purposes. Where it seemed appropriate and helpful, we used visualisation to present the outcome of our analyses drawing on the Pajek (2008) software package, applying the Kamada-Kawai (1989) algorithm to our small datasets (Nooy et al. 2005). Kamada-Kawai is the appropriate approach for the comparatively small datasets we are dealing with as it tends to produce more stable results than other commands (Nooy et al. 2005, loc. 449). Further methodological details are presented alongside the results, where appropriate.

Bibliographic Coupling: Strands of Triple Helix Indicator Work

This section presents the findings of our bibliographic coupling analysis of the 109 TH indicators papers we identified. We carried out cluster analysis as described earlier to get an idea of the different approaches pursued in this area. Table 1 summarises the results. Eight clusters were identified which we reviewed the papers in detail. We also mapped the relationships between the eight clusters, using the same bibliographic coupling and clustering approach. The results are illustrated in Figure 1. The circle size indicates the number of papers associated with a respective cluster. The closer circles are positioned to each other, the more references the represented clusters share. Width of lines between circles indicates the relative strength of links between represented clusters. Interestingly, one can distinguish two groups of clusters – a group that is more closely related to Leydesdorff's 'neo-evolutionary' model (clusters 2, 5, and 6) and another that covers approaches which track the links between science and technology and output of entrepreneurial activity within the university (clusters 1,3,4, 7, and 8). Some of the work in the latter group could be associated rather with Etzkowitz's 'neo-institutional' perspective, while other work in this group stands in a tradition that predates TH thinking and on occasion incorporates ideas and metaphors that can be traced as far back as Price (1965) or even Toynbee (1934). We now discuss the different groups and clusters in more detail.

[1] A complete set of coupling and co-citation analyses at journal, author and other levels would go beyond the scope and scale of a journal article. The authors had to make a selection but are happy to make available other analyses to the interested colleague.

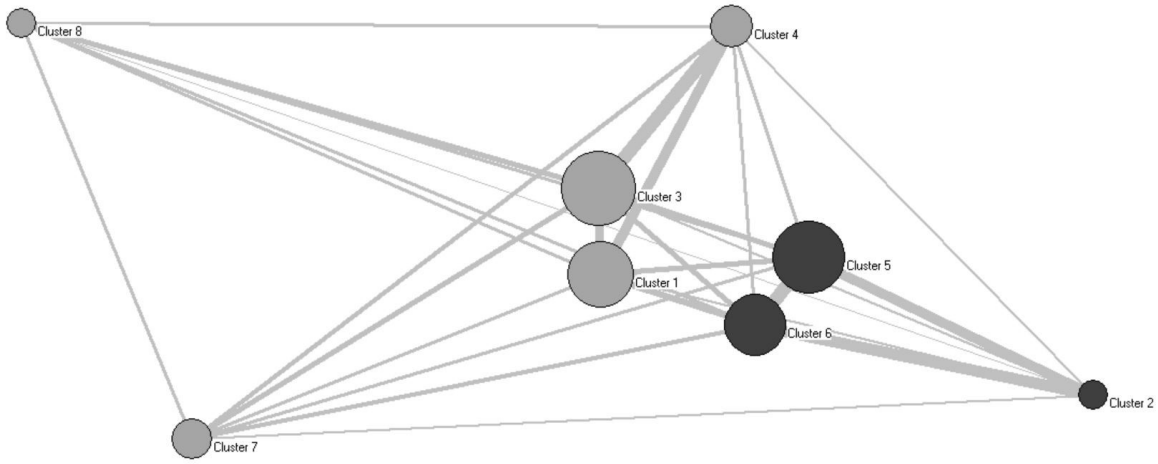

Figure 1. Bibliographic coupling clusters and how they relate to each other

Table 1. Clusters of Triple Helix Indicators papers

Cluster	# Papers	Topic	Highly linked papers	Highly cited papers (# citations)
Group 1: Science-Technology Linkage, the Entrepreneurial University and Governance				
1	20	The metrics of science-technology interaction: focus on patent citations	Acost-RP-2003-1783, Liang-Scient-2012-253, Van Looy-Scient-2007-441, Meyer-Scient-2003-321, Calla-Scient-2006-3	Meyer-Scient-2003-321 (30), Ranga-Scient-2003-301 (22), Van Looy-Scient-2003-355 (21), Acost-RP-2003-1783 (20), Verbe-Scient-2003-241 (17), Van L-Scient-2006-295(16), Calla-Scient-2006-3(12)
3	25	Capturing the entrepreneurialism in universities: commercialisation and patent focus	Baldi-Res Ev-2006-197, Shinn-SSS-2002-599, Ivers-Scient-2007-393, Urang-EPS-2007-1199, Eun J-RP-2006-1329, Acost-Reg St-2009-1167, Marti-JTT-2008-259	Shinn-SSS-2002-599 (70) Eun J-RP-2006-1329 (15) Marti-JTT-2008-259 (12) Langf-RP-2006-1586 (11)
4	8	Multiple perspectives on linking science and technology	Klitk-Scient-2007-491, Stuar-J Inf Sci-2007-231, Meyer-RP-2006-1646, Meyer-ISSI 2-x-34	Heime-Scient-2003-391 (41) Meyer-RP-2006-1646 (39) Meyer-Scient-2004-443 (17)
7	7	Implications of changing Triple Helix relations for governance in academe	Auran-RP-2010-822, Hemli-STHV-2006-173	Lepor-Res Ev-2008-33(12) Hemli-STHV-2006-173 (11)
8	4	Governance of research systems	Ferna-REVIST-2009-251, van H-Innov-2009-443	Lopez-CANADI-2007-201(3) Sande-SPP-2010-689 (1)
Group 2: The Triple Helix, Neo-evolutionary Concepts and Information Flows				
2	4	Structuration of scientific fields and the autopoiesis of	Leyde-Scient-2011-499, Lucio-J Infmtrcs-2009-261	Lucio-J Infmtrcs-2009-261(12) Lucio-JASIST-2009-2488 (2)

		discursive knowledge		
5	23	Applying Triple Helix indicators across the world	Khan -JASIST-2011-2443, Leyde-JASIST-2009-778, Park -RP-2010-640	Leyde-JASIST-2009-778 (17) Danel-Scient-2003-205 (16) Park -RP-2010-640 (11) Glanz-Scient-2007-267 (7) Sun Y-Scient-2010-677(5)
6	17	Information flows in the Triple Helix: entropy- indicators and their theoretical basis	Leyde-Scient-2003-191, Leyde-ENTROP-2008-391, Leyde-RP-2006-1538, Leyde-Scient-2007-207	Leyde-Sc-2003-445(39) Leyde-Sc-2003-191(36) Leyde-JASIST-2004-991(36) Park -Scient-2005-3 (28) Leyde-RP-2006-1441 (25) Leyde-RP-2006-181 (24) Leyde-RP-2006-1538 (23) Campb-HEALTH-2004-64(14)

Note: Papers are presented in abbreviated format, typically the first 5 letters of the first author, a short code for the journal, year of publication and the first page of the article. Journal code: Scient – Scientometrics, RP - Research Policy, SPP – Science and Public Policy, JTT – Journal of Technology Transfer, J Infmtrcs – Journal of Informetrics, Reg St – Regional Studies, Res Ev – Research Evaluation

Group 1: Science-Technology Linkage, the Entrepreneurial University and Governance

The first group consists of five clusters, three of which are closely related to each other. These three clusters address ways to track science-technology interaction (clusters 1 and 4) and entrepreneurial activity within the university (cluster 3). The remaining two clusters are more loosely linked to the core and are concerned with governance aspects that could be of relevance to the Triple Helix measures.

Linking science and technology

Cluster 1 with 20 articles contains a wealth of papers that focus on patent citations as a way of tracking science-technology interaction. It includes regional and technology based analyses as well as contributions that try to understand patent citations better and develop this approach further.

The articles that are linked the most tend to focus on patent citation analysis as the key analytical tool (e.g., Acosta and Coronado 2003, or Callaert et al. 2008), combine patent citation measures with other science and technology indicators to explore correlations between science intensity, scientific and technological productivity (e.g. Van Looy et al. 2007). Other contributions (e.g., Liang et al. 2012, Meyer et al. 2003, or Ranga et al. 2003) take the entrepreneurial university as their starting point to develop and/or apply indicators that can complement patent citations as a measure of Triple Helix relations. These contributions are perhaps the most closely associated with the TH concept as they try to develop indicators that seek to capture aspects of the entrepreneurial activity of university researchers. Here, a lot of the past work concentrates on tracking patents that list university researchers as inventors but are not owned by universities or public funded institutions.

The eight contributions in **Cluster 4** also trace links between science and technology but distinguish themselves by offering broader and at times also comparative perspectives. For instance, Stuart et al. (2007) compare webometrics to co-authorship collaborative data. Inventor-author analysis is another prominent topic in this cluster of papers (Meyer 2005; 2006), often in comparison to other indicators (Meyer and Bhattacharya 2004) or in combination with other measures of science-technology linkages (Klitkou et al. 2007). The focus on papers here is on linking up citation indicators to measures of collaboration and mobility (Heimeriks et al. 2003; Furukawa et al. 2011)

Capturing the entrepreneurialism in universities

Cluster 3 (25 contributions) is mostly concerned with capturing the entrepreneurialism in universities. Unlike contributions in the previous clusters, many have the 'Triple Helix' concept running through the thread of their arguments. The focus is on developing and applying indicators that capture commercialisation, patenting, and a lot of other relevant third mission activity of universities. What has become evident from reviewing influential

papers in this cluster is that many focus on the outcome of TH type interaction in many different cultural, political and geographical settings and systems. These works tend to concentrate on patents, the number of spin offs/outs, the flow of income, the increase in regional prosperity and the presence of knowledge transfer practices. Among the highly linked papers, Baldini (2006) can serve as an illustration. The author reviews the university patenting and licensing literature, summarising that the growth of university patents does not occur at the expense of either their quality or the quality of research but that scientific excellence and technology transfer activities reinforce each other. Uranga et al. (2007) explore the knowledge needed and used in exchanges between universities and industry and demonstrate that the diffusion of knowledge to commercialisation is more complex and current channels are not appropriate. Similarly, work by Acosta et al. (2009), looking at patents taken out by European universities, found that there was strong regional concentration of research and development collaborations between universities and industry. The studies in this cluster are often 'plagued' by methodological challenges, practical difficulties and contextual settings. The article by Iversen et al. (2007) is a case in point describing how the authors have developed a methodology for creating a 'baseline' to measure the impact of academic patenting legislation in Norway after the fall of the 'professors' privilege'.

This cluster also contains reflective work and a brief bibliometric analysis on the Triple Helix itself, such as the contribution by Terry Shinn (2002), which has been cited the most and is also among the most linked ones. Shinn not only critically reflects on the citation impact of the TH at the time but also formulates some challenges of the TH framework in relation to other notions, such as Mode 2 or national innovation systems. Having said this, he does recognise that the TH constitutes a 'serious research school with an empirical and conceptual agenda' (ibid. 619).

Among the other highly cited documents, the focus is again firmly on indicators and TH outcomes. A case in point is the work by Eun et al. (2006) who focus on University-owned-and-run SMEs, exploring the various relationships and structures that are needed to allow Chinese Universities to pursue economic gains, especially given the changes in the Chinese Economic Development landscape. Langford et al. (2006) remind us of the difference between indicators and outcomes and raise the question as to whether proxies are becoming goals. Within the context of Canadian university research, they identify three key issues: (1) current proxies tend to focus on licensing and spin-off but do not measure other important paths of knowledge flow; (2) most readily available proxies are derived from aggregate data which cannot fully capture the idiosyncratic and path-dependent nature of innovation; (3) if targets and incentives of TH actors are skewed or misinterpreted by indicators, actors may engage in counterproductive activities. The work by Martinelli et al. (2008) is an attempt to address the first issue Langford and colleagues raise by presenting a framework that allows the mapping and capturing of knowledge flows beyond licensing and spin-offs, demonstrating that there is a multitude of links between the university and its external environment. In addition, their study explored what individual attitudes were with regards to how their own University was promoting and developing the entrepreneurial agenda. This paper also focuses on the operations of an entrepreneurial university, with the papers mentioned above often focusing only on the outcomes of such operations. Capturing commercialisation-relevant TH processes through indicators, nevertheless, remains a challenge.

Taking a systemic view of this cluster, one observation is that much work on impact tends to focus on patents, how many spin offs/outs exist, the flow of income, the increase in regional prosperity and how the presence of knowledge transfer practices reflect the success or not of the TH. However, little empirical work focuses on the nature of the academic profession, the role of the academy/university and how enterprise, entrepreneurialism, research and the flow back to Universities in a bi-dimensional way are conceptualised and enacted.

What has been researched at a university level is located at the higher maturity level and the area of entrepreneurship or what is often termed 'latent asset[s]' (Lawton-Smith 2013). This has also spawned new research into University 'third stream' income(s) or how to obtain 'industrial funding' (Geuna and Muscio 2009) and in research to evaluate the impact of regional and national knowledge and innovation transfer (Youtie and Shapira 2008).

Implications of changing Triple Helix relations and governance of research systems

The final grouping of papers encompasses a melange of contributions that explore changes in TH relations and/or raise implications for indicator development. **Clusters 7 and 8** encompass an eclectic collection of papers that deal with the implications of evolving Triple Helix relations (Cluster 7) as well as work on the governance of research systems (Cluster 8). Although papers in Cluster 7 do not take the Triple Helix framework as a starting point, they implicitly discuss the consequences of changes in TH components and relations between them. The most linked papers (Hemlin and Rasmussen 2006; Auranen and Nieminen 2010) explore how academe was affected by the unfolding changes. For example, Auranen and Nieminen (2010) looked at the impact of changes in the funding environment on academic publications, paying attention to the increasing role of industry in funding academic research. Hemlin and Rasmussen (2006) discuss changes in the control of academic research quality driven by diversification in the knowledge production system and in particular, by increased emphasis on the connection of science to societal needs. The most cited paper in this cluster by Lepori et al. (2008) argues that changes in a science and technology system, including changes in TH relations, create a need for new science and technology indicators and raise concern about the quality of indicators produced by multiple actors in the decentralised system.

Papers in Cluster 8 deal with the governance of academic research (e.g. López and Robertson 2007; Fernández-Esquinas et al. 2009; van Hemert et al. 2009) and technology transfer from universities to industry (e.g. Sanders and Miller 2010). The highly linked papers discuss changes in the university knowledge production system and challenge the claim of a clear movement from Mode 1 to Mode 2 (Fernández-Esquinas et al. 2009; van Hemert et al. 2009). These papers also consider factors shaping knowledge production systems, for example, organisational power dynamics and the external funding environment (Fernández-Esquinas et al. 2009). Other contributions in this cluster offer insights into the role of discursive practices. López and Robertson (2007), for instance, explore the extent to which the public participates in discourses shaping research activities while Sanders and Miller (2010) look at the role of discursive practices of university technology transfer professionals in aligning the norms in academe and industry. Taking this latter cluster, there is perhaps a need for more collaborative and trans-disciplinary research and for frameworks that allow policy makers to "anticipate and counteract local congestion, resources shortages and the impact of external shocks" (Garnsey 1998, p. 375), which inhibit the TH concept from being predicated.

An emerging issue advocated by Lawton Smith (2011) suggests that the number of countries such as the UK, which use some form of research excellence framework may reduce and threaten the way knowledge is framed and translated to both stakeholders and shareholders and may prevent the 'entrepreneurial university', from being academically entrepreneurial. As areas of indicators mature, much work is empirically grounded, but concentrates on the impact and outcome and to a lesser extent about the value for such interactions. These studies tend to be plagued by different methodological frameworks, practical difficulties and contextual settings, but all have a 'triple helix' concept running through the thread of the arguments. However, there may be need for more meta-analysis based studies.

Group 2: The Triple Helix, Neo-evolutionary Concepts and Information Flows

Information and Meaning Flows, and their Measures

Clusters 2 and 6 are concerned with measuring information flows in knowledge-based innovation systems especially through entropy measures. This strand accounts for about a fifth of all indicators contributions and Loet Leydesdorff's work and his 'neo-evolutionary' approach feature prominently here. Cluster 6 includes the earlier, foundational contributions and theoretical discussions, whereas the smaller Cluster 2 explores the structuration of science fields. Both clusters are rooted in the science communication tradition.

Cluster 6 focuses on information flow in knowledge-based innovation systems and indicators that can be used to measure this flow, with a focus on entropy measures. Two of the highly linked papers in this cluster (Leydesdorff 2003 and 2008) provide theoretical discussions of the measurement of information flow in a dynamic knowledge base through probabilistic entropy indicators. The other two highly linked papers (Leydesdorff and Meyer 2006; 2007) are introductory articles to special issues of Research Policy and Scientometrics devoted to the study of Triple Helix indicators. They provide complementary overviews of the

research frontier and of the interdisciplinary research community working on issues related to Triple Helix indicators at those points in time. Other contributions in this cluster are empirical papers that measure the knowledge base of an economy in terms of entropy indicators (Leydesdorff and Fritsch 2006; Leydesdorff et al. 2006), whereas other articles use webometric, scientometric and technometric indicators to measure national (e.g. Park et al. 2005) or regional innovation systems (e.g. Vilanova and Leydesdorff 2001). **Cluster 2** includes only four papers. The most highly linked papers focus on theorising the communication of knowledge and meaning in social systems from a communication-theory perspective. Lucio-Arias and Leydesdorff (2009) theorise the self-organisation of discursive knowledge (i.e. knowledge that is embedded in texts and that emerges from codification in flows of communication) and scientific communication. In a recent paper, Leydesdorff (2011) extends and reviews his conceptual and operational proposal to study the communication of knowledge and meaning, drawing extensively on sociological system theories like Luhmann's re-elaboration of the theory of autopoiesis or self-organisation proposed by the biologists Maturana and Varela. The other two papers propose ways to operationalise knowledge flows using self-organising concepts (Lucio-Arias and Leydesdorff 2009).

Taking the two clusters as a whole, the data suggest that the area of capturing and measuring the TH in the form of value is less debated and understood in the academic literature. This may be due to the issue of what constitutes value adding, how it is influenced by consumer perception and whether it is heavily influenced by the perceived value the stakeholder and shareholders has of the TH concept rather than what is being done or is in situ. Many of the highly cited papers tend to adopt 'a one off' way of measuring value or outcomes rather than exploring the benefits of the TH over time.

Applying Triple Helix indicators across the world

The 23 papers in **Cluster 5** aim to advance our understanding of science–technology relations by applying Triple Helix indicators to different empirical contexts. The highly linked papers explore longitudinal trends in the network of bilateral and trilateral relations among universities, industry and governments in Asia, specifically in Korea (Park and Leydesdorff 2010; Khan and Park 2011) and Japan (Leydesdorff and Sun 2009). In these papers, the strength of a relation is captured by the indicator measuring the "bits" or "mbits" of "mutual information" in two or three Triple Helix components, using entropy statistics. This methodological approach was inspired by Leydesdorff and Sun (2009), whose paper is most highly linked and most highly cited in this cluster. The 'mutual information' indicators are computed on the basis of data on the authorship and co-authorship of publications from the Science Citation Index and the Arts & Humanities Index (e.g. Leydesdorff and Sun 2009; Park and Leydesdorff 2010) or data on the occurrence and co-occurrence of the words "university," "industry," and "government" in the web-based content (e.g. in blogs, websites, news sites, knowledge sharing sites, online café and bulletin board systems) (Khan and Park 2011).

Other papers in this cluster also make empirical contributions to the literature by presenting long term trends in Triple Helix relations in Europe (Danell and Persson 2003; Glänzel and Schlemmer 2007) and Asia (Sun and Negishi 2010). Older papers trace changes in the volume of research activities in three TH components and use simple indicators, such as the percentage of co-authored publications (Danell and Persson 2003; Glänzel and Schlemmer 2007), to capture the strength of bilateral and trilateral Triple Helix relations. More recent papers use 'mutual information' indicators as well as more conventional indicators (phi coefficients and partial correlation) (Sun and Negishi 2010). While most papers are descriptive, a few try to explain the changes in the strength and variations in relations between TH components by attributing them to government and university policies (e.g. Park and Leydesdorff 2010). The evidence presented here suggests there are no unified ways of comparing one country's or region's approach with another. Several studies have attempted some meta-analysis based studies, but methodological issues with this approach raise questions with the findings.

Co-citation analysis: A knowledge base beyond indicators

The analysis in the previous section has illustrated how rich and diverse work on indicators can be, reflecting the open and inviting character of the Triple Helix framework identifying a number of clusters that could be

grouped in two major strands of work. In this section we will explore the authors cited by the 109 TH indicators papers. Mapping co-cited works allows us to get a more differentiated picture of the 'knowledge base' of TH indicators work.

Co-citation and cluster analysis have been applied to our dataset of 109 TH indicators papers. Methodological details are earlier. We identified eight co-citation clusters. Figure 2 presents a co-citation map of scholarly works that were cited at least 5 times. The circle size of the vertices indicates the citation frequency of individual works. Again, the more frequently works are co-cited, the closer they are displayed on the map. Each vertex, or publication, is labelled with a number for which Table 2 provides further information, in particular the overall citation frequency and number of links to other papers in the cluster. As we will discuss, TH indicators work is not only empirically driven but also anchored in a deeper theoretical context.

To get a better understanding how the eight clusters are related to each other overall we also performed cluster analysis at the level of the cluster. Figure 3 maps the findings (circle size here reflects the number of papers in each group). Again, we can identify two streams of work – one related to 'neo-evolutionary' ideas (clusters 1, 2, 5-7), the other 'neo-institutional' in approach (clusters 3, 4, and 8).

Group 1: The 'Neo-evolutionary' Side of the TH

Work at the heart of the TH

Cluster 1 is located at the heart of the detailed network map of papers **(**Figure 2). It reaches out to both groups of clusters almost equally. Here we find the highest cited paper by Etzkowitz and Leydesdorff (2000, #66 in Figure 2) on the dynamics of innovation. In this paper, published in the influential 2000 Triple Helix special issue of Research Policy, Etzkowitz and Leydesdorff (#66) propose the key concepts of their framework and differentiate it from two other key concepts — national innovation systems and 'Mode 2'-type knowledge production — arguing that there is a shift towards a Triple Helix of university-industry-government *relations*. Unsurprisingly, this paper is closely associated with the work by Gibbons et al. (1994, #67) and two key books on national innovation systems (Lundvall 1992, #49; Nelson 1993, #50).[2] According to Etzkowitz and Leydesdorff (2000, #66), the TH focuses on "the network overlay of communications and expectations that reshape the institutional arrangements among universities, industries, and governmental agencies" (ibid). Consequently, the TH model does not see the firm as the protagonist, which is a key difference to national innovation system models in the authors' view.[3] With respect to normative work by Gibbons et al. (1994, #67) on the new production of knowledge, Etzkowitz and Leydesdorff argue that the "Triple Helix overlay provides a model at the level of social structure for the explanation of 'Mode 2' as a historically emerging structure for the production of scientific knowledge, and its relation to 'Mode 1'" (ibid., section 7). They characterise this process rather as an 'endless transition'. Leydesdorff's (2000, #78) paper explores the Triple Helix in simulations as an evolutionary model of innovation.

[2] Interestingly, closer inspection of citing works indicates that other scholars view the TH as a complementary framework rather than an alternative framework even though they are often discussed as competing concepts.
[3] Etzkowitz and Leydesdorff differentiate the TH from Sábato's (1975) 'Triangle' model in which the state is seen to play a dominating role (Sábato and Mackenzie 1982; cf. Etzkowitz and Leydesdorff 2000).

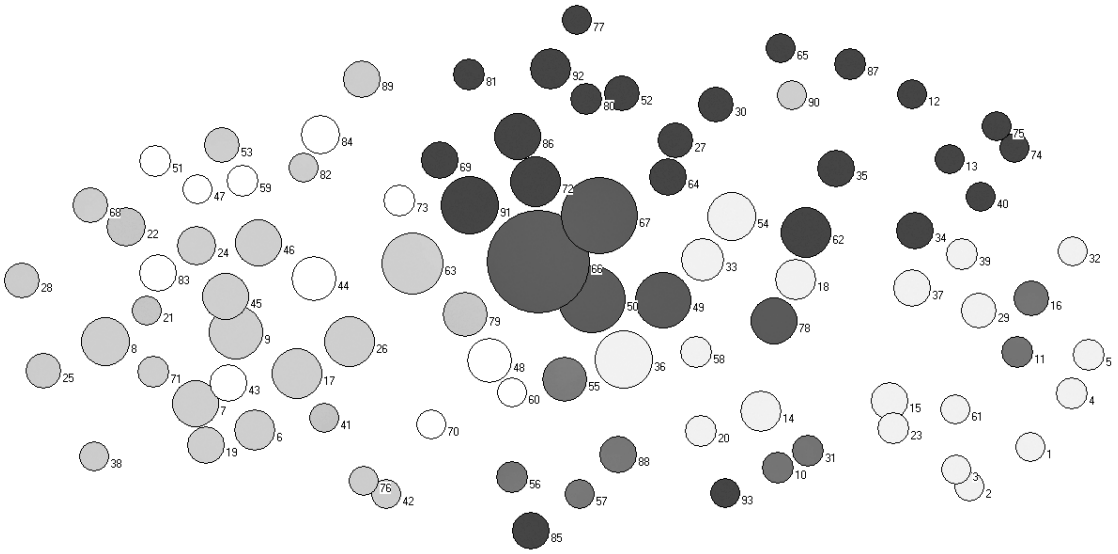

Figure 2. Co-citation map of scholarly works cited by TH indicators papers

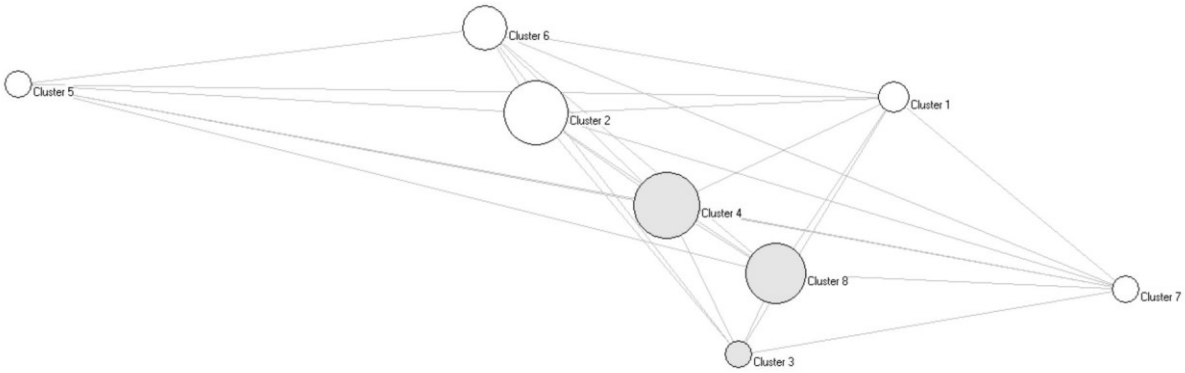

Figure 3. Co-citation clusters and how they relate to each other

Table 2. Co-citation clusters of scholarly works cited by TH indicators papers

Cl.	V	Paper	L	C
Group 1: The 'Neo-evolutionary' Side of the TH				
1	66	ETZKOWITZ H, 2000, V29, P109, RES POLICY	3	62
	67	GIBBONS M, 1994, NEW PRODUCTION KNOWL	1	34
	50	NELSON RR, 1993, NATL INNOVATION SYST	3	27
	49	LUNDVALL BA, 1992, NATL SYSTEMS INNOVAT	2	18
	78	LEYDESDORFF L, 2000, V29, P243, RES POLICY	1	13
2	63	LEYDESDORFF L, 2003,V58,P445, SCIENTOMETRICS	1	22
	9	THEIL H, 1972, STAT DECOMPOSITION A	2	17
	26	LEYDESDORFF L, 2006, V35, P181, RES POLICY	2	15
	17	SHANNON CE, 1948, V27, P379, AT&T TECH J	1	15
	8	ABRAMSON N, 1963, INFORM THEORY CODING	6	14
	7	MCGILL WJ, 1954, V19, P97, PSYCHOMETRIKA	4	13
	46	LEYDESDORFF L, 2009, V60, P778, J AM SOC INF SCI TEC	2	13
	45	PARK HW, 2005, V65, P3, SCIENTOMETRICS	1	13

	6	JAKULIN A, 2004, QUANTIFYING VISUALIZ	1	10
	24	LEYDESDORFF L, 2006, KNOWLEDGE BASED EC	1	9
	19	LEYDESDORFF L, 2006, V35, P1538, RES POLICY	5	8
	89	SHINN T, 2002, V32, P599, SOC STUD SCI	2	8
	28	SHANNON CE, 1949, MATH THEORY COMMUNI	3	7
	68	WAGNER CS, 2008, NEW INVISIBLE COLL	2	7
	53	PARK HW, 2010, V39, P640, RES POLICY	1	7
	25	YEUNG RW, 2008, P1, INFORM TECH TRANS PR	1	7
	71	GLANZEL W, 2001, V51, P69, SCIENTOMETRICS	2	6
	82	ETZKOWITZ H, 2002, MIT RISE ENTREPRENEU	2	5
	38	GARNER WR, 1956, V21, P219, PSYCHOMETRIKA	2	5
	76	DANELL R, 2003, V58, P205, SCIENTOMETRICS	1	5
	90	GODIN B, 1998, V28, P465, SOC STUD SCI	1	5
	42	MATURANA HR, 1980, AUTOPOIESIS COGNITIO	1	5
5	79	LEYDESDORFF L, 2003,V58, P191,SCIENTOMETRICS	1	12
	22	LEYDESDORFF L, 1995, CHALLENGE SCIENTOMET	2	9
	21	DAVID PA, 2002, V54, P9, INT SOC SCI J	2	5
	41	LEYDESDORFF L, 2001, SOCIOLOGICAL THEORY	1	5
6	44	WHITLEY RD, 1984, INTELLECTUAL SOCIAL	3	12
	48	PAVITT K, 1984, V13, P343, RES POLICY	1	12
	84	LEYDESDORFF L, 1998, V25, P195, SCI PUBL POL	2	9
	43	LUNDVALL BA, 1988, P349, TECHN CHANGE EC	5	8
	83	ETZKOWITZ H, 1995, V14, P14, EASST REV	1	8
	51	FREEMAN C, 1988, P38, TECHNICAL CHANGE EC	2	6
	59	DOSI G, 1982, V11, P147, RES POLICY	1	6
	73	GODIN B, 2000, V29, P273, RES POLICY	1	6
	47	FRENKEN K, 2000, V29, P331, RES POLICY	2	5
	60	FORAY D, 2004, EC KNOWLEDGE	1	5
	70	FREEMAN C, 1987, TECHNOLOGY EC PERFOR	1	5
7	55	NELSON RR, 1982, EVOLUTIONARY THEORY	1	12
	88	JAFFE AB, 1993, V108, P577, Q J ECON	1	8
	56	STORPER M, 1997, REGIONAL WORLD TERRI	2	6
	57	BRACZYK HJ, 1998, REGIONAL INNOVATION	2	5
Group 2: The 'neo-institutional' side of the TH				
3	16	TIJSSEN RJW, 2002, V31, P509, RES POLICY	1	7
	10	TIJSSEN RJW, 2000, V47, P389, SCIENTOMETRICS	3	6
	11	TIJSSEN RJW, 2001, V30, P35, RES POLICY	1	6
	31	VAN LOOY B, 2003, V57, P355, SCIENTOMETRICS	1	6
4	91	ETZKOWITZ H, 1997, U GLOBAL KNOWLEDGE E	1	19
	62	MEYER M, 2003, V58, P321, SCIENTOMETRICS	3	15
	72	ETZKOWITZ H, 2000, V29, P313, RES POLICY	2	15
	86	NOWOTNY H, 2001, RETHINKING SCI KNOWL	2	13
	92	ETZKOWITZ H, 2003, V42, P293, SOC SCI INFORM	1	10
	35	MEYER M, 2003, V12, P17, RES EVALUAT	4	8
	64	CLARK BR, 1998, CREATING ENTREPRENEU	1	8
	69	DASGUPTA P, 1994, V23, P487, RES POLICY	1	8
	85	KATZ JS, 1997, V26, P1, RES POLICY	1	8
	34	MEYER M, 2002, V54, P193, SCIENTOMETRICS	1	8
	52	ROSENBERG N, 1994, V23, P323, RES POLICY	3	7
	27	HENDERSON R, 1998, V80, P119, REV ECON STAT	2	7
	30	MOWERY DC, 2001, V30, P99, RES POLICY	1	7
	87	BENNER M, 2000, V29, P291, RES POLICY	1	6

	80	BUSH V, 1945, SCI ENDLESS FRONTIER	1	6
	81	DIMAGGIO PJ, 1983, V48, P147, AM SOCIOL REV	1	6
	65	ETZKOWITZ H, 1998, V27, P823, RES POLICY	5	5
	40	BALCONI M, 2004, V33, P127, RES POLICY	4	5
	12	OECD, 2003, TURN SCI BUS PAT LIC	3	5
	13	SARAGOSSI S, 2003, V28, P47, J TECH TRANSFE	3	5
	77	SLAUGHTER S, 1997, ACAD CAPITALISM POLI	2	5
	74	ETZKOWITZ H, 2003, V32, P109, RES POLICY	1	5
	75	GULBRANDSEN M, 2005, V34, P932, RES POLICY	1	5
	93	LEYDESDORFF L, 2006, V35, P1441, RES POLICY	1	5
8	36	NARIN F, 1997, V26, P317, RES POLICY	1	19
	54	ETZKOWITZ H, 1998, V36, P203, MINERVA	1	14
	33	LEYDESDORFF L, 1996, V23, P279, SCI PUBL POLICY	2	11
	14	MEYER M, 2000, V29, P409, RES POLICY	3	10
	18	NARIN F, 1985, V7, P369, SCIENTOMETRICS	1	10
	15	MEYER M, 2000, V48, P151, SCIENTOMETRICS	3	8
	37	MEYER-KRAHMER F, 1998, V27, P835, RES POLICY	1	8
	29	VERBEEK A, 2002, V54, P399, SCIENTOMETRICS	2	7
	4	SCHMOCH U, 1993, V26, P193,SCIENTOMETRICS	4	6
	23	MCMILLAN GS, 2000, V29, P1, RES POLICY	2	6
	58	MEYER M, 2000, V49, P93, SCIENTOMETRICS	1	6
	20	NARIN F, 1992, V21, P237, RES POLICY	1	6
	39	SCHMOCH U, 1997, V38, P103, SCIENTOMETRICS	1	6
	5	VANVIANEN BG, 1990, V19, P61, RES POLICY	1	6
	1	COLLINS P, 1988, V17, P65, RES POLICY	7	5
	32	ETZKOWITZ H, 1997, V24, P2, SCI PUBL POLICY	2	5
	2	GRUPP H, 1992, P73, DYNAMICS SCI BASED I	1	5
	3	NARIN F, 1998, V41, P51, SCIENTOMETRICS	1	5
	61	NOYONS ECM, 1994, V23, P443, RES POLICY	1	5

Notes: Cl (cluster), V (vertex), L (n of links), C (times cited)

Mutual information, entropy, and sub dynamics

Cluster 2 encompasses approaches that seek to capture triple helix relations in terms of information and communication flows and identify their knowledge bases. This line of work is often based on Leydesdorff's contributions which draw on multiple strands of work, including information theory (e.g. Abramson 1963, #8) and entropy measures (see the prominent positions that the works by Shannon [1948, #17; 1949, #28] and Theil [1972, #9] take in this cluster). Leydesdorff's (2003, #65) paper on the mutual information of university-industry-government relations has been particularly influential.[4] Leydesdorff argues that the TH relations provide a networked infrastructure for knowledge-based innovation systems which organise interacting 'dynamic fluxes' of information that generate 'probabilistic entropy'. Leydesdorff views the 'mutual information' that is shared between the three institutional dimensions as an indicator of this entropy. In Leydesdorff's approach this indicator can take on positive or negative values. If 'negative overlay' is observed, 'self-organisation' may be the result. So it is no surprise that Maturana and Varela's (1980, #42) systematic theoretical biology, which has developed around notions of autopoiesis and cognition, is also part of the cluster reaching out to contributions focused on evolutionary economics.

Cluster 5 (closely related to Cluster 2 as well as 6) extends this perspective towards a framework for empirical research. One of the more cited contributions is the introduction to the first special Scientometrics issue on the

[4] Leydesdorff has worked with a wide range of co-authors to elaborate this model and apply it to bibliometric, webometric and patent data (see e.g. Park et al. 2005, #45; Leydesdorff and Fritsch 2006, #19; Leydesdorff et al. 2006, #26).

Triple Helix of university-industry-government relations (Leydesdorff and Meyer 2003, #79). That particular contribution depicts the Triple Helix as a model of three sub dynamics — economic wealth generation, knowledge-based novelty production, and geographic variety. This perspective views the TH as a framework for an empirical research programme which allows us to appreciate contributions from different theoretical perspectives as specifications of the respective sub dynamics. As the authors put it, the "dimensionality of interfacing the dynamics of economic wealth generation, knowledge-based novelty production, and geographic variety enables us to position the contributions analytically without demanding an integration on the basis of an a priori assumption (like the nation state)" (Leydesdorff and Meyer 2003, p. 199). The sub dynamics present a way to reflect on the "interactions between the organised interfaces (e.g., the political economy and the knowledge infrastructure) which may generate knowledge at a next-order level that feeds back on the local production processes of new knowledge" (ibid.). The knowledge production system is changed as well since it is 'structurally interfaced' with the economy. This is what links this particular perspective on the TH to the work by David and Foray (2002, #21), as well as to Leydesdorff's earlier research on the self-organisation of scientific communications (Leydesdorff 1995, #41) and the knowledge-based society at large (Leydesdorff 2001, #22).

Cluster 6 can be viewed from a perspective of the different sub dynamics encompassing contributions, such as Lundvall's (1988, #43) reflection on innovation as an interactive process, leading from user-producer interactions to a national system of innovation, or Whitley's (1984, #44) work on the intellectual and social organisation of the sciences as increasingly an organised and controlled knowledge production system. Leydesdorff and Etzkowitz's (1998, #84) conference report offers an early discussion of the resultant overlay. Pavitt's (1984, #48) taxonomy also fits into this context as it is able to specify the relations and interfaces between the development of technologies and economic sectors. This paper reaches out to work by other evolutionary economists.

Evolutionary Thinking & Knowledge Spill-overs

Cluster 7 focuses on evolutionary theorising (Nelson 1982, #55) as well as the geography of innovation, especially on regional innovation systems (e.g., Storper 1997, #56; Braczyk et al. 1998, #57) and knowledge spill-overs (Jaffe et al. 1993, #88). Arguably, the work by Jaffe et al. (1993) measuring knowledge spill-overs using patent citations is the most closely associated with Triple Helix indicators work which extends to many works prominently featured in Cluster 1. This small cluster is positioned between the more conceptual strand of work associated with Clusters 2, 5 and 6 (towards the left in Figure 2), the core TH works (Cluster 1 above) and the more science and technology indicator-focused contributions (clusters on the right).

Group 2: The 'neo-institutional' side of the TH

Entrepreneurial universities and university patenting

Cluster 4 is focused on the entrepreneurial university and ways of capturing researchers' entrepreneurial and collaborative activity. The highly co-cited papers and books link conceptual work on norms of academic capitalism (Slaughter 1997, #77) and entrepreneurial science (e.g., Etzkowitz and Leydesdorff 1997, #91; Etzkowitz 1998, #65; Etzkowitz 2003, #92), creating entrepreneurial universities (Clark 1998, #64) that could act as regional innovation organisers (Etzkowitz et al. 2000, #72), modes of knowledge production (Nowotny et al. 2001) to research on indicators, such as university patenting and licensing (OECD 2003, #12; Saragossi 2003, #13), researcher inventions (e.g. Meyer et al. 2003, #62) or other measures at the interface between science and technology (e.g. Meyer 2002, #34). While the latter body of works makes strong reference to the Triple Helix framework and especially Etzkowitz's work on the entrepreneurial aspects, there is another category of contributions that are important but less explicitly linked to the TH. Into this category, for instance, fall the influential papers by Henderson et al. (1998, #27) and Mowery et al. (2003, #30) on the growth of university patenting in the US, the citation rate of university patents and how it has changed over time. The articles have been particularly influential as they discuss these developments in the context of the Bayh-Dole Act. Mowery et al. (2001, #30) suggest that Bayh-Dole has to be seen as one of several important drivers of university patenting and licensing activity while Henderson et al. (1998, #27) observe that university patents

have lost the distinction of being more highly and diversely cited than other patents since the 'explosion' in university patenting in the 1980s. They argue that the rate of increase of 'important' patents that originated in universities was lagging behind their overall increase.

Science-technology linkage

Cluster 8 is mostly related to patent citation indicators. Most of the papers are related to patent citation analysis as a measure of linkage between science and technology (e.g., Narin 1985, #18; Collins and Wyatt 1988; Schmoch 1993; Narin et al. 1997, #36; Meyer-Krahmer and Schmoch 1998, #37). Contributions cited here present a case for adopting this particular method (e.g., Narin and Noma 1985, #18), apply it (Narin et al. 1997, #36; McMillan et al. 2000, #23; Verbeek et al. 2002, #29) or discuss the usefulness of this indicator to measure actual links between science and technology (e.g., Meyer 2000, #14). The rapidly growing citation linkage between US patents and scientific papers is certainly one of the most striking and relatively highly cited observations in this strand of work. Narin et al. (1997, #36) depict them as "useful evidence in arguing the case for governmental support of science" (ibid., p. 317). The evidence reinforced the idea of ever more integrating spheres of academic science, industry and government. So it is not much of a coincidence that this body of work is co-cited with work on the Triple Helix model (e.g., the early special issue in Minerva, Etzkowitz and Leydesdorff (1998, #54)). **Cluster 3** is very closely aligned to the work on patent citation analysis as described above. The papers are by a group of Dutch and Belgian authors, mostly around Tijssen and contribute to the aforementioned debates. The papers tend to use the TH as background before which indicators are discussed rather than a framework for which indicators are to be developed.

Conclusions

Differentiation into at least two main streams of research

The paper has explored the emerging literature on TH indicators and the 'knowledge base' it cites. Even though one might argue the field is very much 'socially constructed' given the strong role special issues have played in aggregating the various approaches of indicators research, it has become clear that work on indicators is not only an emerging area but also a going concern making a substantial contribution to the Triple Helix discourse.

A substantial part of the indicators literature makes an explicit effort to test, model or simulate the dynamics of TH relationships, as we have seen from our bibliographic coupling-based analysis. Interestingly, we can distinguish quite distinct strands: one strand of activity that is seeking to measure overlays, fluxes and dynamics in the trilateral relations, a more recent cluster that applies TH indicators to empirical context often emerging in Asia, and another that also refers to the TH framework but focuses on measuring the outcomes of academic entrepreneurialism as well as problematising related indicators, and finally activity focused on indicators tracking specifically the science-technology linkage. If one aggregates clusters further, two broad streams of activity remain. One stream of activity can be related to TH theorising on information flows and trilateral dynamics, often referring to the work of Leydesdorff, and another strand of work that is associated with the entrepreneurial university and science-technology indicators, esp. patent and patent citations. Articles in this area tend to refer more to work by Etzkowitz. One could argue that the TH indicators literature has begun to differentiate into what Leydesdorff (in press) characterises as a 'neo-evolutionary' stream of work and a 'neo-institutional' perspective.

The analysis of co-citation clusters reinforces the above observations. We find that the TH indicators literature refers to a theoretical or conceptual core which consists primarily of papers and books written and edited by Leydesdorff and Etzkowitz in the late 1990s and early 2000s in which the TH concept was first elaborated but which also includes work by evolutionary economists, such as Nelson, Lundvall and Freeman, as well as science policy analysts, such as Gibbons and Nowotny. This reflects the origin of the TH concept as a notion compared and developed vis-à-vis national innovation systems and the new mode of knowledge production. Apart from the theory focus, the clusters of the 'knowledge base' correspond very well with the bibliographic coupling cluster and strands of the original TH indicators papers. Whether these strands become more self-referential is an interesting issue to explore in future research. Indications are that they could be on their way. There is a

nucleus around Leydesdorff's work that forms a body of work linking neo-evolutionary theory to indicators. Using cluster analysis, we illustrated that 5 of the initial clusters can be associated with this group. Observing the prominence of Leydesdorff's work in these clusters, the term 'neo-evolutionary' may indeed be appropriate. Other links are less forthcoming but it is noteworthy that the second group of clusters tends to refer to work by Etzkowitz as well as early common contributions by Etzkowitz and Leydesdorff. The focus of highly co-cited contributions tends to be more on the entrepreneurial university and measuring exchange between science and technology. In this sense the label 'neo-institutional' may describe a large part of co-cited works in this group adequately. Having said this, authors with an indicators background are very prominent in this group too.

Opportunities for future work

Intriguingly for a research field that scrutinises interaction between practitioners in academe, industry and government, there is relatively little work that is immediately relevant to TH practitioners. Many of the contributions reviewed are still concerned with capturing, measuring and mapping TH relations and activities and a large share of them are descriptive rather than explanatory in approach. This may not be surprising because the body of work studied is primarily about indicators. Impact on practice may well go beyond the scope of work on indicators. Nevertheless, more applied work would be desirable. One opportunity to achieve more impact may be through more reflection of indicators scholars on evaluations and impact studies. New forms of communication and dialogue are needed to ensure both stakeholders and shareholders are aware of the latest thinking and developments informed by practice, policy, praxis and theory. These new ways could take the form of practice-based, problem-solving trans-disciplinary/inter-disciplinary perspectives of the TH.

This would allow for particular contested terrain to flourish, off with the traditional shackles of mainstream academic journal publishing and writing. This new forum could focus on learning from practices, use in practice, using knowledge in new ways, finding knowledge in new ways, translating knowledge into practice in a co-production kind of way, thus allowing the TH to be the TH and not be constrained or sold short by traditional publishing conventions. This perspective would build on and extend work on 'Mode 3' and its extensions to the Triple Helix system and involve knowledge discovery and dissemination enabled by different hybrid organisational forms, structures and governance systems. Why academics engage in academic enterprise and TH based activities remains unclear given the metrics and measures used and studied to date. The distinction and practice between consultancy, enterprise activities, knowledge transfer and contracted academic research is blurred. Earlier work by Clark (1998) and Bercovitz and Feldman (2006) has explored 'becoming entrepreneurial' or 'being entrepreneurial' and the 'connected university' (Kitson et al. 2009). However, much of this work focused on universities doing enterprise, i.e., what they have done in terms of patents, licences, earned consultancy income, etc., not being entrepreneurial, as entrepreneurship is about being and doing (creating and growing), identifying and building on opportunities, and not just feeding on and from them.

Much of the indicators tend to take a partisan view of value/benefit, but this numerical measure inhibits more insights regarding competing contexts for the TH to occupy and its impact(s) on the capability and capacity for enabling technology transfer, which lies at the heart of any TH. What is clear is that existing, rational and mechanistic ways of measuring the TH may not be as appropriate in our current austerity period, as policy makers, owners of businesses and service providers look to the TH as a way of climbing out of deep and even triple dip recession. The TH cuts across many organisation boundaries, with differing diffusion rates and adoption rates, depending on the maturity of the organisation and consumer/beneficiary's expectations. Therefore, more enriched indicators that are multi-layered and multi-dimensional are required to unpick the situation from different and differing angles, thus allowing for the heterogeneity of the different actors to be voiced and heard.

Acknowledgements

This paper started out as a brief research note for the HÉLICE newsletter (Meyer 2012). We would like to thank the editor, Devrim Göktepe, for 'commissioning' this piece of work and are grateful to both guest editors as well as Loet Leydesdorff and Henry Etzkowitz for encouraging comments early on in the process and their

suggestion to develop the paper further. We would also like to gratefully acknowledge the feedback from two anonymous referees.

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