The 'Mobilization-Network' Approach for the Social Network Analysis of Knowledge Mobilization in Science Research and Innovation

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Abstract

The main goal in this paper is to establish a theoretical and empirical basis for the social network analysis of knowledge mobilization in science research and innovation: the mobilization-network approach. The approach captures knowledge mobilization within and beyond academia. A starting point is the identification of knowledge gaps in the investigation of knowledge mobilization, namely in bibliometric studies measuring impact mostly within academia and in name generator techniques relying solely on individuals' recall of network ties. In contrast, networks built using a mobilization-network approach make more *visible* the relations among heterogeneous academic and non-academic actors. These include individual and organisational actors (i.e., researchers, students, policy-makers, funders, laboratory products, and civil-society groups) and mobilization actors (i.e., laboratories, publications, research projects, policies, media events, and business ventures). The longitudinal empirical case study of a basic science laboratory illustrates the approach. Finally, the mobilization-network approach can be an asset for policy-makers wishing to evaluate the impact of science and innovation, especially where knowledge mobilization related policies are in place.

Keywords – Knowledge mobilization, ignorance mobilization, social network analysis, research impact, science and innovation policy, science and innovation evaluation, longitudinal network analysis.

AUTHOR'S NOTE: At a first SNA 'technical' journal that rejected this preprint following pre-publication peer review, the editor commented that "[Actor Network Theory] ANT does not convince as a theoretical approach" although he had originally commented that "[w]hile Latour has a notoriously problematic definition of agency your approach I find to have a level of sophistication that merits further consideration" (Editor at a technical journal, 2013). At a policy-oriented journal, the editor disregarded a reviewer's two editorial judgements to 'publish as is' (editorial judgements appended) and requested in a second round of review that another reviewer's editorial judgement be more fully addressed. In my opinion, however, the second reviewer's comments were ill-founded, lacked clarity and focus, and some would have led the paper astray. One of the suggestions, for example, was to expand a discussion on altmetrics. Though perhaps interesting, such a discussion would be out of scope and stray from a fundamental argument in the approach I propose – not to focus solely on written, explicit knowledge. As the second anonymous reviewer's editorial judgements would be embarrassing to publish owing to what I deem as contradictory and ill-founded content, I do not append them here. I declined to revise in a second round.

I therefore make the paper available as a preprint because my research on peer review has made me aware of the *value* that preprints can hold. I will look forward to feedback on your use of the mobilization-network approach and to see how you adapt it to your needs in the knowledge/ignorance mobilization community and in other epistemic communities. As for future direction, I intend to use the mobilization-network approach in the context of organizational change. Finally, I invite you to peruse my peer review-related preprints on uO Research (in PDF format), including: http://hdl.handle.net/10393/31161 and http://hdl.handle.net/10393/31198.

1. Introduction

The main goal in this paper[1] is to establish a theoretical and empirical basis for the social network analysis (SNA) of knowledge mobilization[2] in science research and innovation. The proposed mobilization-network approach is inspired by actor-network-theory (Latour, 2005) and its edict to follow heterogeneous actors (human and non-human[3]) in a network (see 'follow the network wherever it leads' in Binz et al., 2013, p.1 and Coenen et al., 2012, p.977). Fundamentally, multi-year networks built using a mobilization-network approach attempt to capture and reflect the longitudinal dynamics of knowledge mobilization among heterogeneous actors in science research and innovation, *within* and *beyond* academia. The paper draws mainly from knowledge map scholarship (Chan and Liebowitz, 2006; Eppler, 2001), knowledge mobilization scholarship (Elissalde and Renaud, 2010; Levin and Cooper, 2012), and wider scientometrics[4] scholarship on science research (cf., 'big science', Binz et al., 2013; Evans, 2010; Hermans et al., 2013; Klenk et al., 2010). Finally, the mobilization-network approach contributes mostly to knowledge mobilization scholarship.

An underlying argument here is that although SNA is touted as an important approach to grasp knowledge mobilization beyond academia (Bennet and Bennet, 2007, pp.143-144), most SNA research to date has been limited to impact within academia. I further contend that research has mostly concentrated on impact within academia largely because of the readily available academic publication databases that render bibliometric[5] analysis convenient (see an un-problematized discussion of bibliometric data use in science in Kas et al., 2012, p.4). This means that although academic publication data stored in commercial databases have shaped how many researchers go about investigating science and innovation networks – it is in large part because such data are readily available – not necessarily because the data respond to analytical needs.

Moreover, the mobilization-network approach is pertinent for policy-makers in countries like Canada, the United Kingdom, and New Zealand, and in regions like Europe where science and medical science policies increasingly promote the use of academic knowledge *beyond* academia (Canadian Institutes of Health Research, 2012; Giepmans, 2013; Halliwell and Smith, 2011; Hart et al., 2013; Networks of Centres of Excellence, 2012). These policies tend to promote knowledge uptake such as 'knowledge transfer', 'knowledge translation', or more predominantly in Canada, the United Kingdom, and in Europe, a 'knowledge mobilization' policy approach (Carter et al., 2013; Giepmans, 2013; Greenhalgh & Wieringa, 2011; Halliwell & Smith, 2011). This paper centres on knowledge mobilization. In policy and evaluation circles, the mobilization-network approach proposes to fill a knowledge gap by investigating dynamics

[1] Previous versions of this paper were presented at the Canadian Sociological Association Conference June 6, 2013 in Victoria, Canada, and at the University of Ottawa's 'Mobilizing Network Analysis in Social Research' open seminar August 26, 2013.

[2] Although I only refer to 'knowledge mobilization', conceptually I include 'ignorance mobilization' (Gaudet, 2013). I understand ignorance in science as the limits and the borders of knowing (Gross, 2010).

[3] Actor-network-theory refers to actants instead of actors where an actant can act through the agency of multiple humans or non-humans (Latour, 2005). The importance for Latour (2005) is in not trying to sort out 'real' versus 'fake' agencies (2005, pp.54-55). Fully cognisant of the distinction between actor and actant, I nonetheless use 'actor' to designate nodes in mobilization-networks.

[4] Hess (1977) defines scientometrics as "the quantitative study of science, communication in science, and science policy" (1977, p.75). Callon et al. (1986) expand understanding of scientometrics where quantification is a method that supports the qualitative study of science to address theoretical and policy issues (1986, pp.104,107-108).

[5] Bibliometrics is the study of academic publications including citation, co-citation, keyword (discourse), and author collaboration analysis.

of knowledge within and beyond academia. This is relevant because, in efforts to evaluate knowledge mobilization, policy-makers have mostly had access to approaches focussed on knowledge uptake and impact *within* academia (Buchanan, 2013).

To go beyond impact in academia, this paper harnesses the conceptual approach of *mapping* knowledge from existing scholarship on knowledge maps. The knowledge map (or knowledge cartography, landscape) attempts to render *visible* an intellectual knowledge environment to better characterize, evaluate, and use knowledge in an organization (Chan and Liebowitz, 2006, pp.21-22; Eppler, 2001, pp.1,10). A knowledge map typically consists of a shared context (e.g., visualized business model, a company product, or a firm's value chain) over which a second layer is mapped with individual and organizational structures and explicit (coded) knowledge (e.g., articles, patents, lessons learned, events, databases, or expert systems) (Eppler, 2001, p.2). Of interest for this paper, Chan and Liebowitz (2006) applied SNA to knowledge mapping to create a more effective knowledge management approach. In this new SNA approach, relations were mapped according to main types of knowledge, such as knowledge sharing. A knowledge gap in Chan and Liebowitz's (2006) approach, however, is the exclusion of non-human actors (previously considered in knowledge maps as explicit (coded) knowledge as noted above). In contrast, non-human mobilization actors are integral to the proposed mobilization-network. This leads to the question, what is knowledge mobilization?

Briefly, I understand mobilization as the activation and application of individual or organizational resources towards a goal. Knowledge mobilization then is the use of knowledge towards the achievement of goals (i.e., social, cultural, political, professional, and economic goals) (Gaudet, 2013, p.175). Use here is multidimensional ranging from instrumental, conceptual, strategic/symbolic (Amara et al., 2004; Levin and Cooper, 2012, p.18) and inspirational use (Elissalde & Renaud, 2010, p.414). Finally, the sociologically-informed knowledge mobilization *approach* I adopt looks at processes and dynamics of how academic scientific knowledge is (co) produced, transmitted, received, evaluated, managed and integrated into existing knowledge (discussion in Gaudet, 2013). This paper considers micro and macro-level network dynamics for the mobilization of tacit knowledge (embodied, and not (yet) codified, such as in laboratory manipulations) and of explicit knowledge (i.e., written, oral, and visual) (Collins, 2010).

What is more, the difference between tacit and explicit knowledge, and the difficulties in capturing tacit knowledge mobilization (because of its 'stickiness' or low fungibility, Gaudet, 2013, p.175), draw attention to a disjuncture between what social scientists typically seek to capture (tacit and explicit knowledge dynamics), and the methods and data used to reach the goal. Binz et al (2013) for example, stated the importance of retaining the notion of space in technological innovation systems. Preserving space explicitly recognizes localized knowledge – with low or non-fungible tacit knowledge – within larger international networks (2013, pp.2,3). In spite of highlighting the need to account for tacit knowledge however, Binz et al. (2013) harness network data based solely on explicit knowledge co-publication authorship data (2013, pp.6-7). Binz et al.'s (2013) purported disjuncture between the use of publication data (only partially rendering space 'visible') and their intended purpose is not the exception; it is the norm.

Research on science networks and collaboration tends to privilege the use of authorship and publication data (cf., bibliometrics, Boland, et al., 2012; Klenk et al., 2010; Larivière et al., 2006) instead of a knowledge map approach, even when what is sought includes impact and use beyond academia. Unfortunately however, by its very nature, publication data exclude tacit (and non-published written explicit) knowledge mobilization. Excluded for example are

acknowledgements in publications where authors thank non-author collaborators for products and techniques reflecting mostly tacit knowledge mobilization with spatial data. Further excluded are laboratories where micro-level practices take place (Callon, 1988; Latour, 2005; Woolgar, 1986). Finally, also excluded from publication data is student training where members of laboratories are dispatched around the world to engage in localized learning of tacit and explicit knowledge. The knowledge gap created is one of many in scholarship that sometimes purports to investigate knowledge mobilization beyond academia with methods that tend to restrict data to within academia.

Furthermore, intricately linked with the use of databases are decisions with respect to bounding or setting limits to who is included, and excluded from a SNA. If on the one hand only explicit, written knowledge with aims for impact within academia captures the essence of the dynamics sought, then bounding the network to actors in publication data and co-authorship analysis is justified (i.e., Li et al., 2013). If, on the other hand, tacit and written knowledge, spatial characteristics for such knowledge, and potential impact beyond academia are sought, such as for knowledge mobilization scholarship, bounding must be expanded.

To be sure, that I admonish an apparent over-use of bibliometrics does not take away from its potential, especially when used with an understanding of its limitations or in conjunction with other methods such as interviews (i.e., Jansen et al., 2010), participant observation, and relational journals. The mobilization-network approach explicitly integrates bibliometric analysis, for example.

It would also be mistaken to single out knowledge gaps arising from bibliometrics when knowledge mobilization scholarship likewise engages with methods such as name, position, and resource generators. These allow the development of ego networks based on given individuals (egos). In such methods, egos are prompted to respond to questions that help ‘generate’ names (positions, and resources) of others (alters) with whom they are in relation (Borgatti et al., 2013, pp.263-270). The limitations of solely relying on such name (position, and resource) generators placing undue focus on strong ties (Kadushin, 2012, p.170) and potential memory problems (Knoke & Yang, 2008) are too important to discount however. These limitations also create a barrier to capturing *broader* knowledge mobilization dynamics, revealing additional potential knowledge gaps.

The topic of *broader* knowledge mobilization dynamics shifts the focus to the setting of network boundaries. An *emic* bounded network, to borrow an anthropological term, is one that members themselves identify – also referred to as a natural group. An *etic* bounded network in contrast, is one that researchers impose or theoretically set (see Borgatti et al., 2009, pp.32-35).

To study knowledge mobilization solely with name generators yields an *emic* bounded network based on one (or several) types of relations (i.e., collaboration, sharing) for example, potentially yielding large knowledge gaps about some mobilization actors (cf., weak links, non-human actors). The mobilization-network approach, in contrast, is a combination of *etic* and *emic* bounding. To follow the actors respects the heterogeneous actors involved in knowledge mobilization from their *emic* perspective (cf., full range of relations and activities not set *a priori* by the researcher, from publishing a paper, presenting at a conference, giving an interview to the media, participating in a research project, citing a paper, to setting-up a commercial venture). The added *etic* perspective of bounding includes the researcher temporally bounding the network and setting inclusion and exclusion criteria for actors. Networks built on a mobilization-network approach therefore make more *visible* the micro-level relations among heterogeneous human and non-human individual and organisational actors (i.e., researchers, students, policy-makers,

funders, laboratory products, civil-society groups) and non-human mobilization actors (i.e., laboratories, publications, citing publications, journals, research projects, presentations, policies, media events, patents, and new business ventures). Finally, the mobilization-network approach tends to the knowledge gaps identified above by including knowledge mobilization from non-written knowledge (tacit and explicit), and a broader range of network ties.

The paper proceeds in four parts. First, I propose a conceptual framework leading to the mobilization-network and a discussion on network structure and knowledge mobilization dynamics. Second, I present methodological considerations for an empirical case study, a PrioNet Canada basic research laboratory. Third, I discuss the case study longitudinal mobilization-networks. I conclude with theoretical and empirical propositions and questions.

2. Conceptual Framework

In this section, I elaborate the mobilization-network conceptual framework. I start with a discussion on the difficulties of capturing knowledge mobilization relational data, and how these difficulties relate with bounding a network and SNA. I then look at the dynamics of science and innovation knowledge impact using an interactive model. Building on the model, I propose the mobilization-network approach. Finally, I explore three ideal-type network structures.

2.1 Capturing Knowledge Mobilization Relational Data – Bounding a Network

The entry point to examine the complexity of knowledge mobilization relational data is limitations in bibliometrics and in the use of name generator techniques to bound networks. I start with bibliometric analysis. Although it is an insightful way of investigating knowledge mobilization, it suffers from at least four main limitations. I address three here, and examine a fourth limitation below. Bibliometric analysis can help delve into SNA for publication citations, co-citations, keywords, and collaboration (in articles and in conference abstracts and patents).

A first limitation is the narrow operationalization of potential knowledge mobilization and impact in bibliometrics. Mobilization and impact are largely restricted to the academic realm. This is in part due to the nature of major data sources (i.e., ISI Web of Knowledge from Thompson, or Scopus from Elesvier) that privilege mining data on scientific academic publications (e.g., articles, review articles, book reviews, editorial content, and meeting abstracts). The study of patents and their citation is one exception where bibliometrics extends potential impact outside of academia, including commercially (i.e., Johnson, 2008).

The journal access type is also pertinent, but not incorporated in bibliometric analysis. Open access journals that require no payment from the reader can reach a wider audience outside of academia than subscription and pay-per-view journal models. In addition, "[p]ublishing a journal article is now only the first step in disseminating or communicating one's work; the Web provides a multitude of methods and tools to publicize its scholarly worth" (Meho, 2006, p.36). Bibliometrics does not account for these alternative knowledge mobilization dynamics that can more readily (given the medium) impact beyond academia.

Altmetrics[6] (alternative metrics) analysis is stepping in to fill the bibliometrics gap by measuring alternative metrics for impact beyond traditional citation-based measures (altmetrics, 2013; Chin Roemer & Borchardt, 2012; Priem et al., 2012). Altmetrics include consideration for

[6] "Altmetrics is the study and use of scholarly impact measures based on activity in online tools and environments" (Priem et al., 2012, p.1). 'Webometrics' is an alternative name for Altmetrics.

citations in blogs and social media, metrics on open (or closed) access article views, publication downloads, articles saved, recommended, and discussed, metrics on research datasets and codes, and readership impact indicators (Shema et al., 2012; Shuai et al., 2012; Yan & Gerstein, 2011). Although such metrics have not yet made their way into academic reward systems, and are only slowly being considered by funding agencies as evaluation indicators, it is my contention that they merit consideration when attempting to measure knowledge mobilization beyond academia. A discussion of Webometrics as potential indicators of research scientific quality and impact, for example, was included in the Canadian Expert Panel on Science Performance and Research Funding (2012, pp.61,65,67,72).

Finally, also related to the first limitation is that bibliometric citation analysis generally lacks theoretical framing and instead rests on potentially faulty assumptions about *why* citations occur. Assumptions that citations always underline a positive intellectual tie (or debt) to the cited paper or are an indication of originality in the cited paper can be misleading (Amsterdamska & Leydesdorff 1989; Luukkonen, 1997, p.29). The reasons for citing are much more complex when viewed through the lens of knowledge claim construction (related in Latour, 1987, pp.33-44; classification of reasons for citing in King, 1987, p.265). In a knowledge mobilization context, the focus shifts from *one* overarching implicit *reason* for citing to that of knowledge mobilization dynamics recognizing a range of goals for the actors mobilizing knowledge. Goals do not exclude the use of negative citation, non-essential citation, or citing contrasting ideas (see classification in King, 1987, p.265).

A second limitation is that bibliometric analysis draws solely on *written* explicit knowledge. Such written knowledge is inherently restrictive in large part because it follows a journal editorial peer review process. The latter can shun innovation and is controversial as to its effectiveness in evaluating and validating scientific knowledge reliability (Campanario, 2009; Smith, 2010). Likewise excluded from written explicit knowledge is tacit knowledge (Collins, 2010) – essential to science in practice.

Dedicated knowledge mobilization units in universities attempt to counter the limited mobilization and impact of academic publications (e.g., Research Services & Knowledge Exchange at York University), by producing ‘clear language’ research summaries. Research summary production and subsequent knowledge absorption in stakeholder communities, however, have not been objects of study (Phipps et al., 2013), nor are they yet taken into account in bibliometric analysis.

Third, non-publication knowledge mobilization activities undertaken by scientists (e.g., collaboration with community stakeholders) are also excluded from the scope of bibliometrics by its very definition. Bibliometrics excludes studies other than those of *publication*.

Overall, these weaknesses do not undermine the value of bibliometrics for measuring the importance of knowledge impact in the academic realm where knowledge (re)production is critical. It does suggest, however, that many possible forms and instances of knowledge mobilization remain invisible and unmeasured using this approach.

Beyond bibliometrics, how do researchers attempt to capture knowledge mobilization relational data, including that which precedes and follows scientific publication? SNA research frequently employs variations of name generator[7] techniques in an attempt to elicit and identify relational data in these activities (Borgatti, 2013, p.263-267; Dimitrova et al., 2007, p.10; Knoke

[7] Typically, “[n]ame generators ask respondents to provide a list of contacts with whom they share one or more criterion relations, such as ‘close with’ or ‘friendship’” (Chua et al., 2011, p.106). In science, name generators can elicit lists of contacts for advice, collaboration, or resource sharing.

& Yang, 2008, pp.35-38). What might be missed in the use of these techniques however are potential weak ties (Knoke & Yang, 2008, pp.36-37). Actors typically list strong ties where at most only a few are elicited (Kadushin, 2012, p.170; discussion on forgetting, false recall and distortion in Knoke & Yang, 2008, pp.36-37; discussion on methodological challenges and limitations in Halgin & Borgatti, 2012, pp.39-40). Preceding (and following) publication for example, are multiple knowledge mobilization activities. These can include research projects, experiments in the Principal Investigator's (PI) laboratory or in coordination with other laboratories, training, patenting, and media events. In all of these, weak ties can play important (potentially long-term) roles in knowledge mobilization (Granovetter, 1983, p.214). Name generation techniques appear to be inadequate to explore the full breadth of knowledge mobilization and the variations in tie strength in scientific networks.

In contrast, and although not a knowledge mobilization contribution, Hermans et al.'s (2013) work is an example of researchers carefully avoiding slippage between their proposed object of study (cf., network dynamics of a collaborative innovation network) and their data (cf., experimental research project data on individuals and their relation with organizations and projects) (2013, p.616). In addition, their approach incorporated temporal considerations (15 years of data). The mobilization-network approach follows Hermans et al.'s (2013) example.

The mobilization-network approach also espouses Binz et al.'s (2013) and Coenen et al.'s (2012) *emic*-based network perspective to 'follow the network wherever it goes' (2013, p.1; 2012, p.977). This therefore removes a need to rely exclusively on *eliciting* relational data (cf., name generators) or on *written* knowledge (cf., bibliometrics). Following is a brief discussion on knowledge impact, a precursor to the mobilization-network approach.

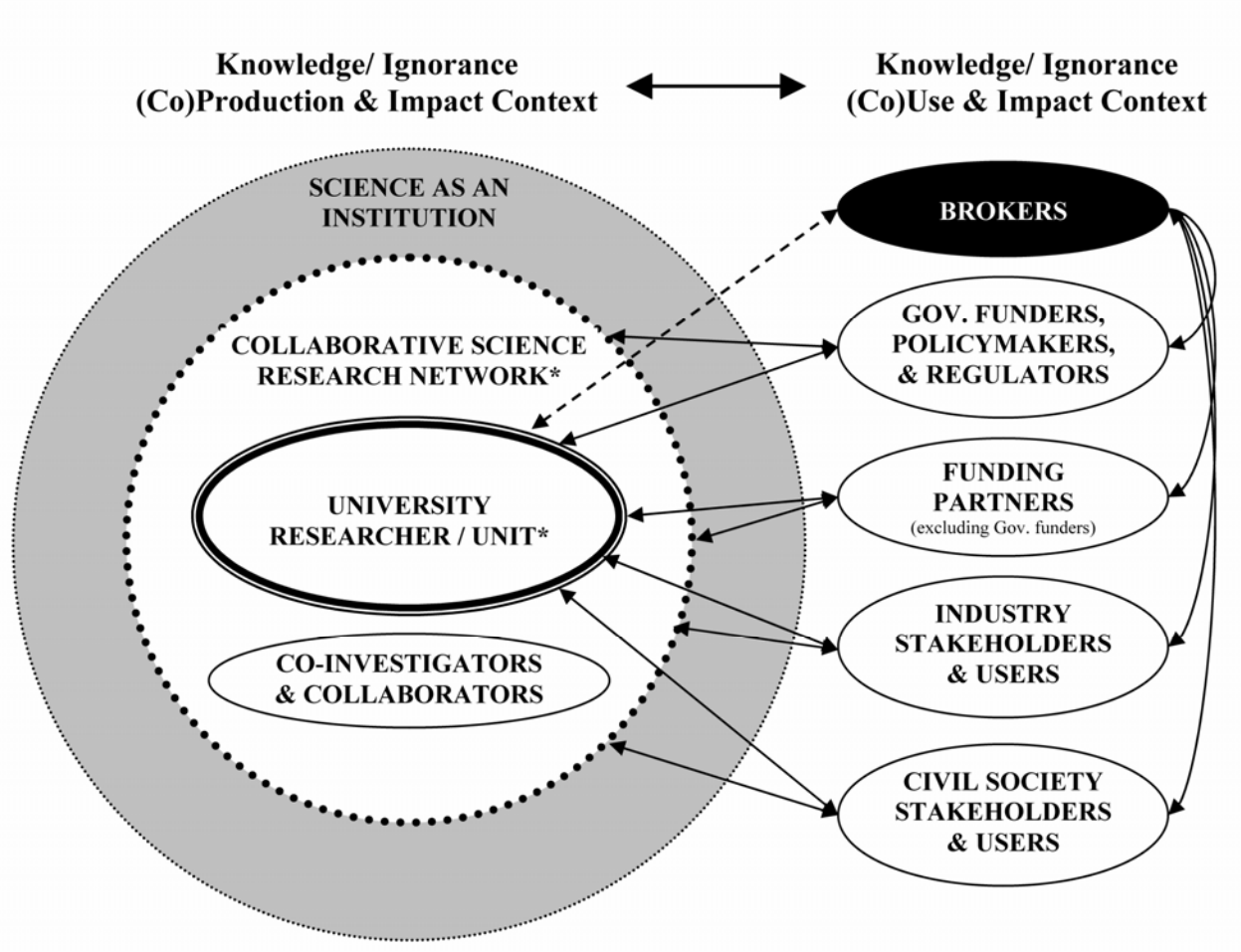
2.2 Understanding Science and Innovation Research Impact

To understand knowledge mobilization and to be able to engage with its SNA raises a fundamental question – what is scientific research knowledge impact? Figure 1 (Gaudet, 2013, p.177) depicts a dynamic model of research knowledge impact with multiple actors in contexts that allow for knowledge production and co-production as well as use and co-use within and outside of academia (left and right side, respectively). Woven into the fabric of the proposed mobilization-network approach are (co)production, (co)use, and impact dynamics.

Research knowledge impact is defined here as changes resulting from scientific knowledge mobilization within and beyond science as an institution. Within academia, impact generally relates to knowledge (re)production (cf., generating new research questions, new laboratory procedures, or further publications). Beyond academia, however, impact includes "…the influences of research on policy, managerial and service delivery practices, or on political and public discourse" (Nutley et al., 2007, p.282) and knowledge or material products. Scientific knowledge impact can therefore take place in the (co)production and (co)use contexts, or both.

The interactive model was inspired by Levin & Cooper (2012, p.20), but holds distinct theoretical and conceptual bases. Briefly, I understand the left-hand (co)production context as a perspective where scientific knowledge is constructed or co-constructed, and validated (cf., mobilized) within science as an institution. As indicated above, bibliometrics tends to study knowledge mobilization in the academic (co)production context (left-hand academic side) where impact is investigated using citation, co-citation, discourse use, and collaboration. The right-hand (co)use context, in contrast, is a perspective where scientific knowledge is mobilized outside of science as an institution for a variety of goals.

Figure 1. Science and Innovation Knowledge Research Impact Interactive Model (Gaudet, 2013, p.177)



*University Researcher (Laboratory), Unit, or Network levels are as applicable.

What is more, there is a heterogeneous set of actors in both contexts. In the left-hand context, researchers, co-investigators and collaborators fall under the institution of science. Moving to the right-hand (co)use context, the first group of actors is knowledge brokers who can be experts *inside* or *outside* of academia (i.e., knowledge mobilization research units embedded in universities). Brokers generally serve as bridges between the two contexts and can facilitate (co)production of knowledge (Bielak & deGraaf, 2011, p.19).

Succinctly, the other groups of actors can also deploy mobilization strategies with a variety of goals. The governmental role, for example, includes identifying and funding research, regulating activities, and overseeing policy development and implementation, some of which can involve brokers (Bielak & deGraaf, 2011). The influence of non-governmental funding on knowledge mobilization frequency or functioning is particularly relevant in the context of understanding the impact on academic research (see Evans (2010) for impact of industry partnerships). Finally, industry and civil-society stakeholders mobilize knowledge for multiple uses. In the next phase, the mobilization-network takes shape.

2.3 Conceptualizing the Mobilization-Network

Conceptually, mapping knowledge is rooted in scholarship on knowledge maps (Eppler, 2001, pp.1,10; Chan & Liebowitz, 2006, pp.21-22). Relevant for this paper is Chan and Liebowitz's (2006) application of an SNA approach to knowledge mapping. The proposed mobilization-network approach builds on the idea of making knowledge more *visible* – SNA here makes knowledge mobilization *relations* more visible.

Overall, the mobilization-network accounts for (co)production, (co)use, and impact within and outside of academia in Figure 1. Theoretically, the mobilization-network helps further understanding of knowledge mobilization through science network structures and can help investigate variations at the actor level. Empirically, the mobilization-network is an attempt to capture and represent network structures with the use of knowledge mobilization relational data (adapted from Knoke & Yang, 2008, p.8).

To develop a knowledge mobilization network using actor-network-theory is to follow the actors themselves (Latour, 2005, pp.121-122; also see 'follow the network wherever it leads' in Binz et al., 2013, p.1 and Coenen et al., 2012, p.977) in order to trace mobilization associations. Heterogeneous members create ties with other members of the *same class* of actors. Furthermore, to follow the actors is to follow when *new* associations are made (Latour, 2005, p.79). In science networks, this means studying *new* knowledge mobilization associations. These associations are temporally sensitive – longitudinal data are gathered from a start, to an end time.

The mobilization-network class of actors is further subdivided into three sub-types: individual human and non-human actors, organizational actors, and non-human mobilization actors. These actors are associated according to one relation, knowledge mobilization. Human and non-human individual actors include researchers, students, individual funders, individual policy-makers, nature (i.e., human tissue samples), and collaborators. Organizational actors include governmental entities (e.g., scientific organizations, departments, and ministries), not-for-profit organizations, businesses, not-for-profit or private funding organizations, and non-governmental scientific organizations. Mobilization actors, the third type of actors, serve as the 'glue that binds' the network actors. It is through mobilization actors that individual, organizational actors and mobilization actors associate and mobilize knowledge to reach goals. Examples of mobilization actors include laboratories, publications, citing publications, 'clear language' research summaries, research projects, presentations, media events/products, patents, journals, conferences, training opportunities, products (including procedures), new business ventures, and government policies, regulations, legislation, or programs. Supplementary Tables 1 and 2 (appended), detail mobilization-network relational data ties and nomenclature.

What is more, because non-human actors can relate with other non-human actors (cf., a publication in relation with a journal), this yields a hybrid network. Typically, networks are one-mode when one type of entity relates with the same type of entity (cf., human to human) or two-mode when one type of entity (cf., humans) relates with a second distinct type of entity (cf., activity). The mobilization-network as hybrid network includes human to non-human relations and non-human to non-human relations. This means that the mobilization-network is not a 'pure' one-mode (human to human) or two-mode (human to mobilization activity) network (see hybrid designs in Borgatti et al, 2013, p.282).

Fundamentally, non-human mobilization actors are the cornerstone of the mobilization-network approach. Knowledge mobilization conceptualized as between individual human actors falters in great part, I argue, because of the extensive assumptions embedded in these

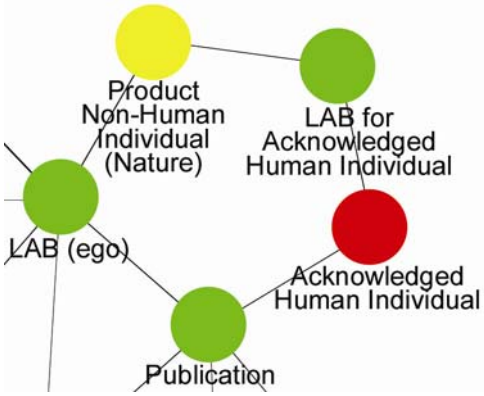
associations (i.e., faulty assumptions embedded in author-cited author relations or author-author relations). Here I touch on a fourth limitation for bibliometrics. In research projects for example, Highly Qualified Personnel (HQP, as technicians and graduate and post-doctoral students) often entertain hierarchical relationships with their supervisor who, in turn, holds network relationships with some peers in the network. SNA depicting HQP authors as linked with all other authors for a given publication would therefore prove erroneous. Following the actors would reveal no evidence of such knowledge mobilization flows or associations with HQP.

Publication acknowledgements serve as an example of the value of following the actors in a mobilization-network. Figure 2 features a sample acknowledgement for knowledge-related services. The non-human mobilization actor (publication) is in relation with the acknowledged human individual and with the ego network laboratory (excluding all other actors for illustration purposes).

In contrast, in Figure 3, rich relational data become *visible* when providing a product is the reason stated in the acknowledgement. The social scientist can thus retroactively *see* knowledge dynamics by following the actors as they entered the network, contributed to research, and subsequently to the publication. In Figure 3 therefore the non-human mobilization actor (publication) is in relation with the acknowledged human individual, who is in relation with a laboratory, who in turn relates with the non-human individual product (here in the role of nature), who finally relates with the non-human knowledge mobilization laboratory (ego). This example captures tacit knowledge embedded in a product (nature) flow from an acknowledged human actor.

Figure 2. Cut-out detailed depiction of node to node ties for a human individual actor acknowledged in a published paper for having provided knowledge-related services

Figure 3. Cut-out detailed depiction of node to node ties for a human individual actor acknowledged in a published paper for having provided a product



Furthermore, an assumption embedded in the mobilization-network is that from one science network to another, mobilization actors can differ. This is due to the use of actor-network-theory. Empirically, to follow the actors means doing away with preconceived notions of what to expect as mobilization actors and *de facto* excludes the *exclusive* use of databases. ISI Web of Knowledge or Scopus can be used (i.e., to generate citation data, publication data, and to validate data), but not exclusively.

To generate SNA data for a mobilization-network, therefore, there are at least two starting points. For an ego-network (cf., a laboratory), a place to start is an individual researcher's *curriculum vitae*. For a whole-network with reporting obligations (usually for funding purposes), a place to start is institutionally validated reports. Lists of mobilization actors above and in Supplementary Table 2 (appended) gives a sense of actors that can be encountered.

Moreover, in a mobilization-network, accounting for temporality is critical and cumulative. Even if relationships become latent or are weak, they *remain* in the network over time given that knowledge mobilization actors leave *quasi-permanent* traces as they engage in relations. Not only does this allow for the investigation of latency to activity relationship mutations, but it also facilitates comparative analysis between networks.

An additional consideration for mobilization-networks is the multi-method approach – quantitative SNA *and* qualitative methods. Investigating an ego network solely using a *curriculum vitae* would probably only yield a partial mobilization-network, for example. Qualitative interviews, surveys, relational journals (cf., produced by a PI where relations are logged daily for a set temporal period), and participant observation are complementary methods that can help follow the actors and enrich not only the mobilization-network but also understanding for network dynamics. In addition, one of the limitations of using reporting data or *curriculum vitae* is that knowledge mobilization activities that do not lead to a final knowledge product (i.e., published article, oral or poster presentation, patent, company) remain invisible. Yet, knowledge mobilization has occurred or has been blocked[8]. Through interviews, surveys, relational journals, or participant observation the researcher can elicit associations that did not yield a final product, but that did mobilize (or not) knowledge.

Finally, I return to one of the strengths of the mobilization-network – its sensitivity to temporal dynamics. For multi-year projects and for scientists' career span, the conceptual approach helps investigate short and long-term knowledge mobilization and impact. From an initial research project in year one, for example, cumulative mobilization actors (e.g., papers, oral and poster presentations, media events, patents, products, and further research projects) forge *visible* network dynamics fostering knowledge mobilization *within* and *beyond* academia. In the case of journal publications, long-term analysis can help overcome the problems of lengthy academic publication timeframes by not missing subsequent potential mobilization and absorption in the knowledge use context (e.g., through media events, policies, stakeholder events or knowledge products, and patents).

Although the mobilization-network is conceived as a hybrid network, policy-makers and science network evaluators can nonetheless still explore human to human relations by extracting a part of the hybrid network to a one-mode network. Such one-mode networks must be interpreted with caution, however, and take into account that they represent *potential* interaction

[8] An example in the PrioNet laboratory case study is the Principal Investigator's reluctance to engage with a company with respect to potential commercial collaboration and product development. Also, see Evans (2010) for an analysis of contrasting knowledge mobilization sharing dynamics between industry and academic science research actors.

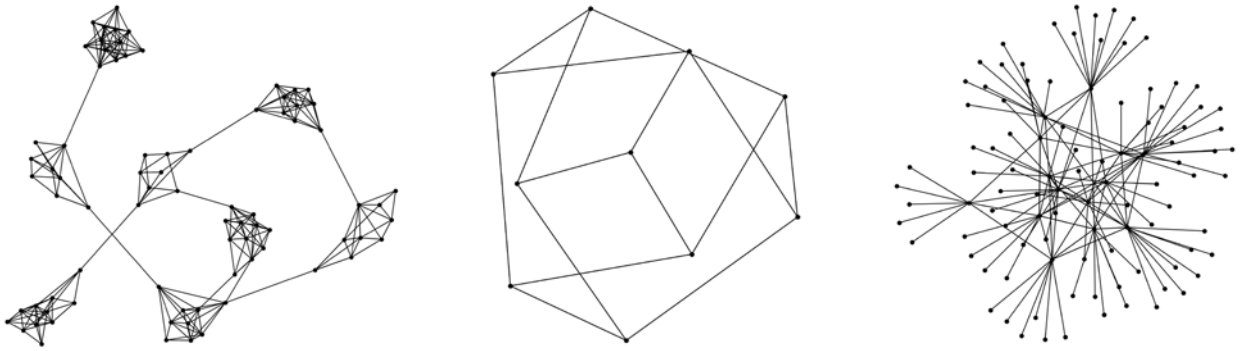
among human actors (discussion of limitations of extracting one-mode networks in Borgatti et al, 2013, pp.234-236). Before I tend to the case study, I broach ideal-type network structures.

2.4 Three Ideal-Type Network Structures and Knowledge Mobilization Dynamics

Of the many ideal-type network structures in SNA, here I discuss three that inform macro and micro-level interaction. The three ideal-types in Figure 4 are clique (or cellular) network, diffuse network, and core/periphery network (see Borgatti, 2005).

First, the clique network displays groups of actors clustered in cliques (or cells), which means that actors within the cliques are not well connected to actors in other cliques, but are well connected within cells. The actors who connect two cliques through bridges are designated as cutpoints (Borgatti et al., 2013, p.17). Cutpoints are vital for inter-clique knowledge mobilization because removing a cutpoint can lead to the loss of relations with another clique. From a knowledge mobilization standpoint, cliques can help foster innovative knowledge mobilization with reduced opportunity of being 'normalized' by dominant thinking (related in Borgatti, 2005). The presence of cliques can also reflect knowledge mobilization in a context different from that in which it originated (cf., from within to outside of academia).

Figure 4: Three Ideal-Type Networks – Clique, Diffuse, and Core/Periphery



1. Clique 2.Diffuse 3.Core/Periphery

Second, actors in the diffuse ideal-network interact with several other actors who are typically different from actors with whom other actors interact (Borgatti, 2005). Borgatti (2005) framed relations in a diffuse network in SNA terms where "[t]he property of having ties to people who are not in the same social circles with each other is betweeness or "structural holes". A person rich in structural holes has many ties, and the people they are tied to are not tied to each other" (2005). This means such actors in the network are not necessarily exposed to the same knowledge mobilization (as would be the case in cliques or cells), but perhaps multidisciplinary knowledge with different tacit and explicit knowledge mobilization and mobilization inside and outside of academia.

Finally, the core/periphery ideal-network structure displays a dense core with well inter-connected key actors (with higher density) and actors with fewer connections at the periphery (lower density). As such, the well-connected actors in the core structurally hold potential to contribute to higher mobilization than those at the periphery. Overall, this ideal network type is very dense and most actors tend to be well connected (notwithstanding the core/periphery differences), which means that knowledge mobilization flows are (fairly) homogeneous,

especially in comparison to a clique (cellular) ideal-type network. If a mobilization-network displayed these types of characteristics, temporal dynamics of an actor moving from the periphery to the core could indicate increased mobilization, for example. Overall, this ideal type displays a (fairly) homogeneous core, and diverse peripheral actors with the core actors playing a critical role in much of the knowledge mobilization. Knowledge mobilization concentrated within academia would reflect this ideal-type at the core. From ideal-types, the paper now considers methodology.

3. Method

The theoretical and empirical basis for the SNA study of knowledge mobilization presented above is based on empirical research. First, it is based on a whole network SNA for PrioNet Canada from 2005 to 2011 (not explored in this paper). Second, it is based on SNA for an individual case study laboratory in PrioNet Canada (ego network SNA, explored below). PrioNet Canada was launched in 2005 as part of the Government of Canada's Networks of Centres of Excellence (NCE) program. Its mandate included the coordination of Canada's research and policy response to the impact of prion diseases in Canada (PrioNet Canada, 2012, p.1). NCE Networks of Excellence typically perform R&D and knowledge mobilization and commercialization activities (NCE, 2011, p.2).

The case study elaborated in this paper is a basic research laboratory in the PrioNet Network laboratory, an ego network where the PI's laboratory is the ego. It is important to specify that the laboratory is a basic research laboratory given that such basic research typically does not lend itself to immediate knowledge mobilization outside of academia. To the contrary, basic research typically leads to more questions and further mobilization mostly within academia. Applied research laboratories in contrast, tend to concentrate on applying research knowledge, including outside of academia.

In addition, the data for the ego network was collected from five sources. First, the PI's *curriculum vitae* (that listed publications and presentations (oral and poster)). Second, in-person interviews with all team members in the laboratory (that provided details on training/exchange opportunities outside the laboratory, details on the establishment of a research unit in the laboratory, details on potential knowledge users outside of the laboratory and academia, and details on advice relations). Third, reporting tools for PrioNet Canada (that listed research project details for those in which the PI led or collaborated). Fourth, citation data from Web of Science and Scopus (for eleven scientific articles published from 2005 to 2011 containing at least one author from the laboratory case study). Lastly, citation data from Google Scholar™ (for the same articles, to capture grey literature citation). These data sources yielded human and non-human actors and their relations from 2005 to 2011. Supplementary Table 3 (appended) lists the attributes associated with the actors.

Furthermore, the PI validated publication, presentation, and project funding relational data (to render project HQP anonymous resources non-anonymous with individual HQP names). As part of the validation exercise, the PI also provided details on relations between non-human mobilization actors using EXCEL spreadsheets (with seven years of data). Where applicable, he added ties between publications and research projects, publications and presentations (oral and poster), publications and HQP training, presentations (oral and poster) and research projects, and presentations (oral and poster) and HQP training.

Finally, the data were analyzed using ORA NetScenes SNA software. The network maps in this paper were generated using ORA NetScenes 2D visualizer with a spring embedded layout. The following section presents empirical results and a discussion for the case study.

4. Results and Discussion

I communicate brief descriptive results for the case study with an integrated discussion. First, I outline descriptive characteristics for the ego network. This sub-section includes a comparison between the mobilization-network approach and bibliometrics. Second, I explore SNA network maps for the case study and mobilization-network dynamics in 2005, 2006, and 2011. Finally, I explore a one-mode network for human to human relations in 2011.

4.1 Descriptive Ego Network Characteristics

Table 4 features the actor type count and a few overall network characteristics from 2005 to 2011. From a small network with only 10 nodes (actors) and 14 reciprocal ties among these nodes in 2005, the case-study mobilization-network grew to 366 nodes networked with 750 reciprocal ties in 2011 and increases in knowledge mobilization flows every year. The mean degree (mean number of ties to each node) increased from 2.8 in 2005 to an average of 4.1 in 2011, revealing that on average, actors increased their number of new mobilization relations over the seven year span (notwithstanding a small decrease in 2006).

Table 4: Actor Type* Count and Network Characteristics for the Case Study Mobilization-Networks

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Actor Types							
HIA	3	22	27	46	51	76	94
NHIA	0	0	6	9	9	9	15
NHMA	7	28	43	87	132	194	248
OA	0	5	5	9	9	9	9
Network Characteristics							
Size (# nodes)	10	55	81	151	201	288	366
Ties (# ties)	14	74	133	278	397	585	750
Mean Degree	2.8	2.69	3.28	3.68	3.95	4.06	4.1

*Actor Types: human individual actor (HIA), non-human individual actor (NHIA), non-human mobilization actor (NHMA), and organizational actor (OA).

Continuing with Table 4, human individual actors and non-human mobilization actors increased their numbers every year indicating new mobilization relations for network actors. In addition, although non-human individual actor absolute numbers remained small (ranging from six in 2007 to fifteen in 2011), these actors were critical to making tacit knowledge exchange from around the world visible (mostly laboratory material sharing, including from organizations and universities in the USA, from Norway, and from Canadian universities). Moreover, embedded in human individual actor counts were individuals that the laboratory acknowledged in peer-reviewed papers, making tacit and explicit knowledge mobilization visible (from around the world), that typically remains invisible in bibliometrics.

Finally, comparing the approach with bibliometrics, a bibliometric collaboration analysis for this laboratory would have networked zero publications in 2005 and 11 publications over seven years (until 2011), involving a total of 17 unique authors and co-author collaborators. In 2011, the bibliometric collaboration analysis would have therefore only accounted for four percent of the mobilization-network. In another example, a bibliometric citation analysis would have yielded a blank network in the first year (with zero citations) culminating in the final year with 76 papers citing case study publications (removing self-citation). The 76 papers represent only eleven percent of the mobilization-network in 2011.

Comparing the richness of actors in the mobilization-network from Table 4 with bibliometric data, bibliometric analysis would have also missed considerable knowledge mobilization beyond written explicit and peer reviewed knowledge. Citation analysis would have maintained the invisibility of impact beyond academia for citation actors, overlooking the open access properties of publications, shunning non-peer reviewed written communication, and ignoring the intended audience of citing publications. In the case study mobilization-network for example, four of the laboratory's papers were open access, which yields greater potential for mobilization beyond academia. Two non peer-reviewed written communication pieces published on-line mobilized knowledge beyond academia for a wider audience. Finally, five citing publications were also beyond academia, including two associated with Alzheimer research and three in the area of pharmaceutics and therapeutics that aimed to reach pharmaceutical and therapeutic scientists with potential ultimate *applied* commercial goals.

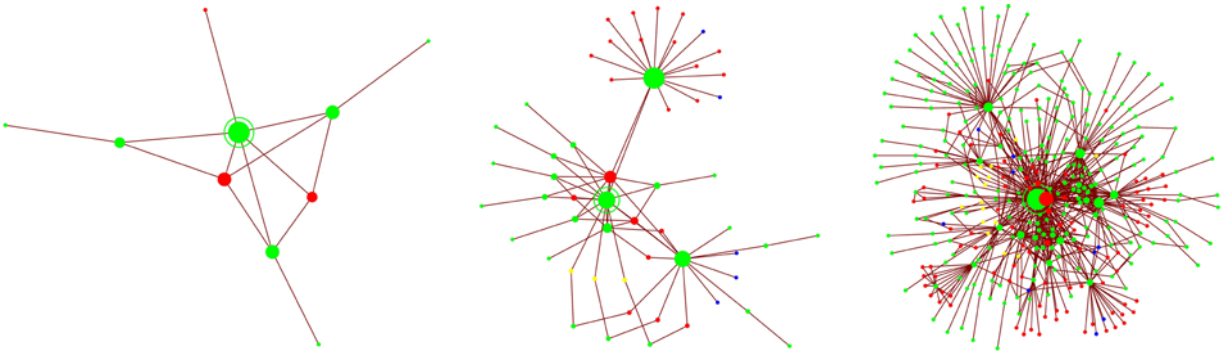
A final example highlights mobilization beyond academia. One of the laboratory research assistants took up employment outside of academia, bringing his tacit and explicit laboratory knowledge to a federal government setting. From his new post, he continued to relate with the ego laboratory members – this was critical given his extensive tacit knowledge. Bibliometric citation and collaboration analysis could not help gain these insights. In the case study, a combination of document analysis and interviews brought the actor's changing mobilization role and context to light.

4.2 Overview of SNA for the Ego Networks

Moving to SNA *per se*, figures A.5 depicts the mobilization-network maps for the first (2005), second (2006) and final (2011) years of the ego-network case study (other years not shown). The ego in the maps (circled in green) is the laboratory and alters are individual and organizational actors and mobilization actors.

The maps in figure 5 illustrate some of the ways in which the actors relate. Examples include: (1) human individual actor (PI) to mobilization actor (research project), (2) non-human individual actor (product in the role of nature) to mobilization actors (ego LAB and other PI's LABs), (3) organizational actor (government agency) to mobilization actor (research project), and (4) mobilization actor (peer reviewed paper) to mobilization actor (journal). As indicated above, a mobilization-network coding scheme and list of potential non-human mobilization actors is presented in Supplementary Tables 1 and 2 (appended). In Figure 5, individual human, non-human, and organizational actors are colour-coded (see note in Figure 5).

Figure 5. Mobilization-Network Maps for LAB-R ego network* with human and non-human *individual* actor, *organisational* actor, and *mobilization* actor relation dynamics for 2005, 2006, and 2011**



2005 2006 2011

*Maps generated with 2-D Visualizer by ORA-NetScenes and a spring embedded layout. Node size reflects total degree centrality where larger nodes have more ties with other actors. LAB-R (in green), the ego, is circled in green. Years 2007 to 2010 are not shown.
**green=non-human mobilization actor, blue=organisational actor, red=human individual actor, yellow=non-human individual actor

Briefly, I first investigate dynamics for a specific actor – a funded research project. In year two, the ego LAB joined a first (of seven) multi-year research project, a non-human mobilization actor (the 'star' shaped extension at the top of 2006 of Figure 5). Initially, the research project brought in new mobilization relations to the whole network with human individual actors (HQP and collaborators, including national and international networked actors) and organizational actors. Over seven years, network dynamics constructed a more central role for the first research project as relations with multiple non-human mobilization actors increased (cf., three papers, thirteen presentations, one training exchange, and five poster presentations). These fostered further tacit and explicit knowledge mobilization. In the 2011 map in Figure 5, it had moved to a more central actor role with its forty-three reciprocal links (now located to the right of the ego LAB). For policy-makers, this temporal movement is especially important to understand the interplay between research funding and knowledge mobilization.

Furthermore, with respect to macro-level network structure, the maps for all years (including those not shown in Figure 5) retain some elements of core/periphery dynamics where there is a tendency for central actors to hold denser links with other central actors in comparison to outlying actors. The ego LAB, the PI, and other ego LAB actors retain many of these core roles in the network.

Given the seven year span, however, the movement of some periphery actors to the core can be observed, such as for the research project example above. What is more, actors that joined the network in the last year had very little opportunity to reach the core and increase mobilization given that time is an important factor in these movements. The majority of protruding actors in the 2011 map in Figure 5 consists of journals citing publications from the ego LAB. Once more, this reflects a temporally sensitive process – citation.

Moreover, intermingled in the core/periphery network layout are 'quasi-clusters' that sometimes migrate to the core/periphery structure, while some remain outliers. A few 'quasi-

clusters' cases reveal a lack of further knowledge mobilization even after seven years. This type of stagnation reflects the social construction of knowledge in science where actors value and mobilize some knowledge actors, whereas others remain dormant (with potential for future mobilization). The nature of the case study's knowledge mobilization practices, a basic research laboratory, no doubt influenced the type and intensity of knowledge mobilization activities (see footnote 8 above).

4.3 Extracting a One-Mode, Human to Human Relations Network Map

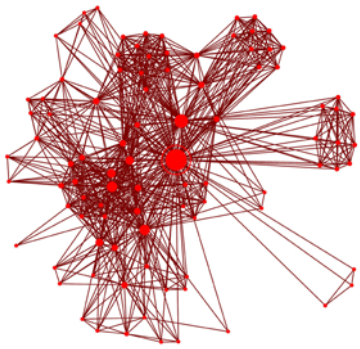
In Figure 6, I present a one-mode, human to human relations network map for the year 2011. The 2005 one-mode map contained only three actors (as per Table 1, and pictured in Figure 5, year 2005), therefore a network map did not provide insights into network structure. In contrast, the 2011 one-mode map in Figure 6 contains 94 human actors as they relate among themselves, based on their 'affiliation' with mobilization actors. This means that two actors that held a relation with a publication, for example, would be portrayed as having a link in Figure 6, and therefore the *potential* for interaction.

It is important to stress the *potential* for interaction because interviews with laboratory members and literature cited above revealed that the PI is usually the only member of a LAB who regularly directly engages with other PIs and other researchers, authors, and collaborators to mobilize knowledge through non-human mobilization actors. Only exceptionally do HQP engage with alters. In Figure 6, most of the central actors are HQP, and the PI is circled in red. The size of nodes reflects total degree centrality, where larger nodes hold a higher number of ties with other actors. As for maps above, all actors hold a series of attributes that allow for further detailed analysis depending on evaluation or analytical needs.

The network structure in Figure 6 once more closely reflects a core/perhiphery ideal-type with some clustering at the periphery. The cluster at the bottom-right, for example, is a research project launched in 2011 and who's mobilization activities occurred after the data collection period (of which this paper, Gaudet, 2013, a poster presentation, and numerous oral presentations). The cluster in the middle of the right-hand side of the map also corresponds to a research project with a collaborator's laboratory that does not appear to have extensively engaged in knowledge mobilization with the case study PI.

This type of one-mode map also provides insights into human actors who play critical roles in linking two or more research projects and other activities, and mobilizing knowledge between/among these. An example is the node in the middle of the top of the map that joins two 'clumps' of actors (to its left and its right) from two different research project non-human mobilization actors. Another influential actor is the Scientific Director of PrioNet Canada who joins HQP in the core of the map, slightly above and to the left of the PI. The Scientific Director's key mobilization role undoubtedly reflects the value constructed for the case study's knowledge mobilization in the PrioNet Network. These brief empirical insights and discussion lead to the following conclusions.

Figure 6: 2011 LAB-R ego network map* human *individual* actor to human *individual* actor potential knowledge mobilization



*Map generated with 2-D Visualizer by ORA-NetScenes and a spring embedded layout. Node size reflects total degree centrality where larger nodes have more ties with other actors. LAB-R (in the centre), the ego, is circled in red. Years 2005 to 2010 are not shown.

5. Conclusions

Four findings stand out for the mobilization-network approach. First, in contrast to bibliometrics, the approach renders written and non-written tacit and explicit knowledge mobilization more visible, within and outside of academia. Second, following the actors means that the approach retains sensitivity to context and to an *emic* bounding of the network reflecting those engaged in knowledge mobilization. Third, longitudinal SNA can help policy-makers evaluate impact within and beyond academia at a macro-level for ego and whole networks, and at a micro-level for specific actors (such as a funded research project). Finally, when PIs validate and detail relations between mobilization actors, this can be especially pertinent for policy-makers evaluating mobilization at the research project funding level. It can help answer questions such as, what is the time delay between research project funding and knowledge mobilization? In what form is project knowledge mobilized and where? How does HQP training impact knowledge mobilization for a laboratory?

What is more, the empirical data sources (e.g., reporting documents, *curriculum vitae*) reveal a paradox. Governmental research funding agencies and universities tend more and more to embrace knowledge mobilization strategies to catalyze and enable research (co)production to (co)use dynamics *beyond* academia. Paradoxically however, reporting, funding, and promotion processes in these organizations tend *not* to value *non*-peer reviewed publications and *beyond* academic knowledge mobilization activities as highly as those *within* academia. The paradox is undoubtedly not lost on actors engaged in science (related discussion in Provencal, 2009).

To be sure, the mobilization-network approach holds limitations, including challenges related with access to data, with access to actors for data validation and collection, and with a preference for sometimes-elusive longitudinal data sources. An important limitation is its time-consuming methodology. By forgoing easily accessible datasets and by following knowledge mobilization actors wherever they lead, the social scientist must stay close to the object of study, be open to surprise, and constantly re-evaluate inclusion/exclusion dynamics in the network. Depending on *emic* and *etic* bounding decisions, the researcher must therefore engage in tedious searches to locate and characterize network actors.

In spite of potential limitations, theoretical contributions from the mobilization-network approach are valuable based on three criteria (of four proposed by Hess, 2010). First, theory can

"challenge taken-for-granted assumptions" (2010, p.1). In this paper, the main assumption challenged is that only human actors mutually engage in networks. In contrast, mobilization-networks *mutually* relate human and non-human actors. Second, theory can help generate new research venues and questions. Here I propose new questions and approaches with respect to what a relation means in knowledge mobilization, and how to broaden the understanding of SNA beyond academia for knowledge mobilization. Finally, Hess (2010) proposed that to evaluate the relevance and value of new theoretical contributions is to "…assess its potential to contribute to policy issues" (2010, p.2). The mobilization-network can contribute to research policy at the university level, at the research network level, and at the granting agency level. As discussed, what is *valued* as impact for knowledge mobilization makes its way into reporting and reward systems. By making non-academic (yet potentially critical, including economically) knowledge mobilization impact visible in the mobilization-network, policy-makers will have much-needed tools to adjust indicators for research and innovation reporting and the academic reward system.

To conclude, knowledge mobilization is frequently constructed as 'win-win' for researchers, stakeholders, funding agencies, and taxpayers. How best to understand it, however, as an object of study *itself* through SNA, and understand its impact? The mobilization network approach only begins to address such science in practice and science policy questions.

Acknowledgements – The author thanks anonymous reviewers for their editorial judgements, Stéphanie Gaudet and Nathan Young for comments on earlier drafts, and the PrioNet Canada case study laboratory PI, Xavier Roucou, and his students, post-doctoral fellows, and research assistants. The ideas, arguments, analysis, and remaining errors are solely the author's, however, and do not necessarily reflect the views of individuals above. Funding was provided in part by a Joseph-Armand Bombardier Canada Graduate Scholarship from the Social Sciences and Humanities Research Council of Canada, an HQP research assistantship in a PrioNet Canada research project directed by Nathan Young, and from a PrioNet Canada travel grant.

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A reviewer's editorial judgements at a policy-oriented journal (see Author's note, page 1)

Reviewer's editorial judgement at round 1:

* Is the paper likely to be of significant interest to readers of Research Policy, taking account of both the subject matter relative to the scope of the journal and the insight it offers about that topic? (If you feel it is not, then please explain your reasons for this, and then you do not need to go on to provide a full review.)

This is a relevant paper for this journal and the broader field to the increasing pressure of a) mobilizing research knowledge beyond academia and b) demonstrating the impact of research in order to justify public expenditures.

* The importance of the questions raised, the significance of the paper's contribution, and the originality of its addition to our knowledge of the area.

This author provides a clear conceptual framework and method to measure knowledge mobilization efforts that go beyond mere bibliometric analysis. It is an important contribution as it addresses many of the limitations of previous Social Network Analysis on this topic.

* The appropriateness and soundness of the conceptual/theoretical framework, the methodology, the data, the analysis and the conclusions drawn.

The conceptual framework integrates diverse stakeholders and is well conceptualized; however, it might be helpful to include a framework which shows the different kinds of Non-Human Actors, mobilization Actors, and other sources used in a data analysis framework showing these types and where they fall within academia and outside academia. Not needed for acceptance or publication, just something for the author to think about. The analysis and conclusions are interesting, especially the fact that bibliometric analysis alone captured only 4% of the mobilization activities!

* The robustness of the argument and the clarity of the writing.

This paper is very well written, and I suggest it be accepted for publication with one minor change listed below:

-what does the short form cf. mean in parenthesis (page 8)? It is used many times and I am unfamiliar with it, please provide explanation for readers *[**Author's note**: I addressed this with a reference to the use of 'cf.' in papers already published in the policy-oriented journal. I must admit that I am influenced by a German researcher who frequently uses this abbreviation. I have noticed that it does not have the same uptake across disciplines.]*

Great article! As someone who researches in the field of Knowledge Mobilization, I found it a valuable contribution to the field. This is a solid article well grounded in the literature with clear conceptual framework and method. Sectors have been struggling with how to measure

knowledge mobilization efforts and research impact, and this study presents a tangible rationale and method to do so both within academia and beyond.

Reviewer's editorial judgement at round 2:

I thought the article made a good contribution to the knowledge mobilization field (which is my area of expertise and the area upon which all my research studies are based). I also think the author provides VERY thorough responses to all of the second reviewers comments. As such, I think this is ready for publication; I know many of my colleagues would be very interested in this paper, and its attempt to apply Social Network Analysis in a way that goes beyond bibliometrics to capture knowledge mobilization processes.

Supplementary File: The 'Mobilization-Network' Approach for the Social Network Analysis of Knowledge Mobilization in Science Research and Innovation

Supplementary Table 1. Proposed Coding Scheme for Non-Human Mobilization Actors (in alphabetical order)*

Non-Human Mobilization Actor	**Proposed Coding Scheme****
Citing Publication	YYYYCIP01, YYYYCIP02 […] YYYYCIP*i*
Conference	YYYYC01, YYYYC02 […] YYYYC*i*
Government policies, regulations, legislation, or programs	YYYYG01, YYYYG02 […] YYYYG*i*
Interview (i.e., print, radio, and electronic media)	YYYYIN01, YYYYIN02 […] YYYYIN*i*
Invited Oral Presentation at a Conference	YYYYIOPC01, YYYYIOPC02 […] YYYYIOPC*i*
Invited Oral Presentation at a Venue	YYYYIOPV01, YYYYIOPV02 […] YYYYIOPV*i*
Journal	J01, J02…J0*i*
Laboratory	LAB-(acronym or full name) (i.e., LAB-Singh)
Oral Presentation at a Conference	YYYYOPC01, YYYYOPC02 […] YYYYOPC*i*
Oral Presentation at a Venue	YYYYOPV01, YYYYOPV02 […] YYYYOPV*i*
Organization	Use name or acronym (i.e., Transmissible Spongiform Encephalopathies (TSE) Unit = TSE Unit)
Patent	YYYYPA01, YYYYPA02 […] YYYYPA*i*
Poster Presentation at Conference	YYYYPPC01, YYYYPPC02 […] YYYYPPC*i*
Publication, Academic Journal	YYYYP01, YYYYP002 […] YYYYP*i*
Publication, Web-based	WEB01, WEB02 […] WEB*i*
Research Project (with year span)	RP01(YYYY-YYYY), RP02(YYYY-YYYY) […] RP0*i*(YYYY-YYYY)
Training	Relevant acronym (i.e., Canada-Europe Exchange = CDN-EURO-XCH)
Venue (for presentation)	YYYYV01, YYYYV02 […] YYYYV*i*

*List of non-human mobilization actors is not exhaustive and not all actors can be found in Figure 2. 'To follow the actors' means the list can never be definitive as it can potentially change from one analysis to another.
**For large networks (i.e., a collaborative network with several laboratories), numerical sequences become 001-999 or 0001-9999 (instead of 01-99 as for the smaller network depicted in Figure 2).

Supplementary Table 2. List of mobilization-network relational data details for mobilization actors (in alphabetical order)*

Mobilization Actor	**Relational Data (actor to actor ties)**
Citing Publication (that cites a LAB (ego) publication)	Publication - Citing Publication Citing Publication – Journal (or Web)
Commercial Entity (i.e., pharmaceutical company)	Commercial Entity – LAB (ego) Commercial Entity – Owners (1, 2…*i*)
Government Policies, Regulations, Legislation, or Programs	Policies (or other) – Research Network and/or LAB (ego) Policies (or other) – Researcher (1, 2…*i*)
Interview (i.e., print, radio, and electronic media)	Interview - Interviewee (1, 2…*i*) Interview – LAB (ego)
LAB (ego)	Laboratory – Human Individual (1, 2…*i*) (i.e., HQPs, PI)
Patent	Patent – LAB (ego) Patent – Author (1, 2…*i*)
Presentation (oral invited, oral not-invited, poster)	Presentation – Presenters (1, 2…*i*) (i.e., HQPs, PI) Presentation – LAB (ego) Conference/Venue – Presentation *If applicable:* Presentation – Training (validated with LAB (ego) PI) Presentation – Publication (validated with LAB (ego) PI) Presentation – Research Project (validated with LAB (ego) PI)
Products (or Procedures)	Product – LAB (ego) Product – Author (1, 2…*i*)
Publication (Scientific)	Publication – Author (1, 2…*i*) Journal – Publication Publication – LAB (ego) Publication – Acknowledged Individual_1 Acknowledged Individual_1 – LAB-Acknowledged Individual_1 LAB-Acknowledged Individual_1 – Product (1, 2, …*i*) Product (1, 2, …*i*)- LAB (ego) Publication – Acknowledged Organizational Actor Publication – Acknowledged Individual_2
Research Project (when the PI is not with the LAB (ego), but rather with another laboratory)	Research Project – Main Researcher (PI) Research Project – Main Researcher (PI) LAB Main Researcher (PI) LAB – Main Researcher (PI) Research Project – LAB (ego) Research Project – PI for LAB (ego) Research Project – Collaborator, Co-investigator (1, 2, …*i*) Research Project – HQP (1, 2, …*i*) for Main Researcher LAB Research Project – HQP (1, 2, …*i*) for LAB (ego)

	Research Project – Partner Organization (1, 2, …*i*) LAB for Main Researcher – HQP (1, 2, …*i*) for Main Researcher LAB
Research Project (when the PI is with LAB (ego))	Research Project – PI for LAB (ego) Research Project – LAB (ego) Research Project – Collaborator, Co-investigator (1, 2, …*i*) Research Project – Partner Organization (1, 2, …*i*) Research Project – HQP (1, 2, …*i*) from LAB (ego) Research Project – HQP (1, 2, …*i*) from other LAB(s)
Training (for HQP)	HQP – Training PI for Host Training – Training LAB-Host Training – Training LAB-Host Training – PI for Host Training LAB (ego) – Training *If applicable:* Training – Research Project (validated with LAB (ego) PI) Training - Publication (validated with LAB (ego) PI)

*Relational ties list is not exhaustive given that to 'follow the actors' means that mobilization actors will vary from one network to another.

Supplementary Table 3. List of Social Network Actor Attributes (format or category listing)

Year Span (*from* YYYY *to* YYYY)
Actor Type (Human Individual Actor (HIA), Non-Human Individual Actor (NHIA), Non-Human Mobilization Actor (NHMA), Organizational Actor (OA))
Main Role (Knowledge Mobilization Actor, Acknowledgee, HQP, PI, Nature, Partner, Collaborator, Co-author, Funder, Citing)
PrioNet or Not
Funded by (Names of funders)
Tacit-Explicit
KM type (communication, science in practice (for training))
KM sub-type (conference, invited oral presentation, oral presentation, poster presentation, article, conference and venues, journal, laboratory, research project, website, thesis)
Audience-Primary (science, wider)
Geo (country level)
Level (LAB, University, Province, National, International),
Location City
Location Province
Discipline
Academic Institution
Other affiliation