Social Network Analysis: A Complementary Method of Discovery for the History of Economics

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Forthcoming in: *A Contemporary Historiography of Economics*, E. Roy Weintraub and Till Düppe (eds.), Routledge.

Abstract

In this chapter, we discuss social network analysis as a method for the history of economics. We argue that social network analysis is not primarily a method of data representation but foremost a method of discovery and confirmation. It is as such a promising method that should be added to the toolbox of the historian of economics. We furthermore argue that, to be meaningfully applied in history, social network analysis must be complemented with historical knowledge gained by other means and often by more traditional, mostly qualitative, methods. It should therefore be viewed as a method that complements rather than replaces more established approaches in the history of economics.

1. Introduction

Relations of various kinds have always been part of the subject matter of the historian in general and the historian of economics in particular. They are a major factor in scientific knowledge production. Economists collaborate, use similar methods, and share their results. Science as a social enterprise has instantiated mechanisms for feedback on research and allow for critical discourse, all features that emphasize the relational character of science. And as in any other discipline, albeit to different degrees, it holds also for economics that the process of knowledge production takes place in a setting that can be characterized largely by way of such varied relations. Understanding relations and their impact is therefore essential for any historian of economics.

Network analysis is increasingly used in history. It allows for studying multiple types of relations and how they operate (Borgatti et al. 2009, Düring/Keyserlingk 2015, Lemercier 2015, Whetherell 1998). More specifically, network analysis encompasses a set of innovative theoretical, mathematical, statistical, and computational tools for analyzing, modeling and understanding networks. The main task of *social* network analysis (hereafter: SNA) is to study relations between social entities, be they individual actors, organizations, or groups of

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people (Wassermann/Faust 1994, 3). It can also be applied to study relations among non-human entities, such as publications, organizational affiliations, institutional structures, and many others. In either case, (social) network analysis allows to systematically analyze relational and attribute data in order to better understand latent structures and hidden patterns.

Applied to the history of science, SNA offers a distinctive perspective on knowledge production by systematically treating relationships among interacting scientists as relevant (i.e., explanatory) factor. Moreover, the unit of analysis is usually not the single scientist but rather a whole set of entities and the relations between them. As SNA presupposes that those relationships have a non-arbitrary effect on how knowledge is produced, relations play an explanatory role in understanding knowledge production. Furthermore, it allows for a formalization and systematic characterization of those relations and the entities connected in virtue of those relationships. Besides capturing the most basic idea of the existence or non-existence of a relation, SNA allows us, among various other things, to study (1) the intensity and closeness of a relationship; (2) the centrality of an entity, for instance, of an actor or various actors in a group; (3) the structural positions that entities can occupy in the larger context of their network; and (4) the temporal changes of those relations.

So far, SNA has been rarely used in history of economics. One exception is an extensive study of the emergence of subfields within the discipline of economics in the second half of the 20th century (Claveau/Gingras 2016). Another paper has studied the diffusion of rational choice theories within economics and across the social and behavioral sciences from the 1940s onwards (Herfeld/Doehne 2018). Again, another study has analyzed a network of Viennese scholars in the early 1920s (Wright 2016). These three papers already indicate that SNA can tackle a diversity of historical issues. To us, the wealth of SNA in the broader literature in history and historical sociology demonstrates that we have only scratched the surface of the potential applications of the method in the history of economics.

Our aim in this article is to discuss this usefulness of SNA for the history of economics. While we acknowledge that SNA confronts a range of limitations, we argue that it is a promising method for the field. We make two main points about SNA. First, contrary to what is sometimes assumed, it is not primarily a method of data representation, but foremost a method of discovery and confirmation. It is as such a promising method that should be added to the toolbox of the historian of economics. Second, to be meaningfully applied in history, SNA must be complemented with historical knowledge gained by other means and often by more traditional, mostly qualitative, methods. It should therefore be viewed as a method that complements rather than replaces more established approaches in the history of economics.

2. Network Analysis as a Method of Discovery and Confirmation

While this chapter is not meant as a detailed introduction to SNA, the following terminology sets the conceptual ground for what follows. SNA tries to analyze (1) a phenomenon that either possesses relational properties or can be modelled from a relational perspective. The researcher produces what we call (2) 'network structures' to model some of those properties of the phenomenon. In its simplest form, a network structure, or for short a network, is "a collection of points joined together in pairs by lines" (Newman 2010, 1). It includes a set of nodes and a set of edges (or ties) connecting some or all of the nodes. Nodes and edges also have attributes such as identifiers, weights, or more substantive attributes such as variables for socioeconomic status. A network consisting of such nodes and edges can be stored in various formats. Small networks can be written down on a piece of paper or even stored in someone's mind. Networks are however typically stored on computers in form of matrices of nodes and edges, with their respective attributes. Network structures can also be visualized as graphical representations (often called sociograms). To produce what we call (3) a 'network representation', some of the attributes of nodes and edges must be mapped onto visual properties such as colors, diameter of circles, thickness of lines, etc. Other visual properties must be added such as, most notably, the positioning of the nodes in space.[2]

A research project can produce a network representation of some social phenomenon without this project being an instance of SNA. In this section, we illustrate this possibility by contrasting one example of SNA to an example of a historical study that builds a network representation but does not use the tools of SNA. We contrast both cases to better characterize what SNA is and what it can do for the historian of economics. Thereby, our point is not normative: we do not claim that the study not using SNA is defective. In fact, we believe it to be an instance of high quality historical research. However, this contrast helps us to illustrate the added value of SNA for the historian of economics.

More specifically, the characteristic that we want to highlight is that SNA serves foremost as a *method of discovery and confirmation*, and not primarily as a *method of representation*. The graphical representation of a network is not the core of SNA. Rather, its core is a set of techniques, sometimes computational and statistical, sometimes quite informal, to *search for features* in a network structure. This search can lead to discovering properties of the structure that could have otherwise remained undetected. In this case, SNA serves as a method of discovery in that the researcher explores the network in order to generate new, but fallible

[2] For detailed introductions to SNA and its techniques, see Wassermann/Faust 1994 and Scott (2000). See Claveau/Herfeld (2018) for a short overview of the use of SNA in the history of economics.

knowledge claims, which can then be tested with other methods. The search can also lead to confirming or disconfirming hypotheses already entertained, hypotheses that are perhaps supported by other sources of evidence. In this case, SNA serves as a method of confirmation in that the researcher uses SNA to test a previously formulated hypothesis. In both cases of discovery and confirmation, SNA helps the researcher learn (always fallibly) about the system under study.

The point about the secondary role of graphical representation in SNA merits emphasis because many newcomers to SNA seem to misinterpret it as primarily a method of representation. They consequently produce the now frustratingly common representations of 'hairball networks' (see Figure 2 for an example). But staring at a hairball typically generates little knowledge. Of course, graphical representations of networks do not always look like hairballs. They can be highly informative. More specifically, they can have at least two functions.[3] First, a researcher can use the network representation as an informal means of discovery or confirmation. If the network has salient properties, representing it graphically can indeed be sufficient to learn much about its structure (this role of representation will be discussed more fully in Section 2). For instance, if a network has fully disconnected components (i.e., some groups of nodes share no edge with the rest of the network), a graphical representation using any standard layout algorithms will make this feature salient. The learning toolkit of SNA thus includes the technique of inspecting a graphical representation of the network.[4] But there is no requirement to use this specific tool to be doing SNA. Using the same example, any specialized software can find for us the number of fully disconnected components of a network structure. There is thus a way to learn the same property without going through the process of manually inspecting a graphical representation.

The second function of a network representation is to convey information *to others*. A network representation, provided it is no hairball, can indeed be an efficient way to let others understand some research results. Taking again our network with disconnected components, a researcher who discovered this property by writing the following line of code in R "is_connected(g)" (where g is the network object)[5] might decide to produce a graphical representation for her readers to see the disjoint structures and thus understand almost instantaneously this property. However, what makes this research a case of SNA is not the

[3] For a discussion of other goals of network representations when it is used at the start of the phase of data analysis (e.g., finding coding errors), see Section 2, step 5.
[4] This technique has recently been used in the history of economics by Claire Wright (2016), see her Figure 1.
[5] This function is part of the igraph package in R (Csardi/Nepusz 2006).

graphical representation of the network, but rather the technique used for discovery (which is not relying on graphical representation in this case). In reverse, there are research projects that do not use the techniques of SNA for discovery and confirmation but use a network representation to convey the results. This strategy should not be confused with SNA.

Let us illustrate this contrast and the way in which it indicates the usefulness of SNA for the history of economics by comparing two research projects. The first project is from Kevin Hoover in the early 1990s and did *not* rely on SNA. Hoover (1991) wanted to understand the lineages of research in the new classical macroeconomics. One of the major results of this research project is the network representation reproduced in Figure 4.1.

Figure 11.1 A table of kinship and consanguinity for the new classical macroeconomics

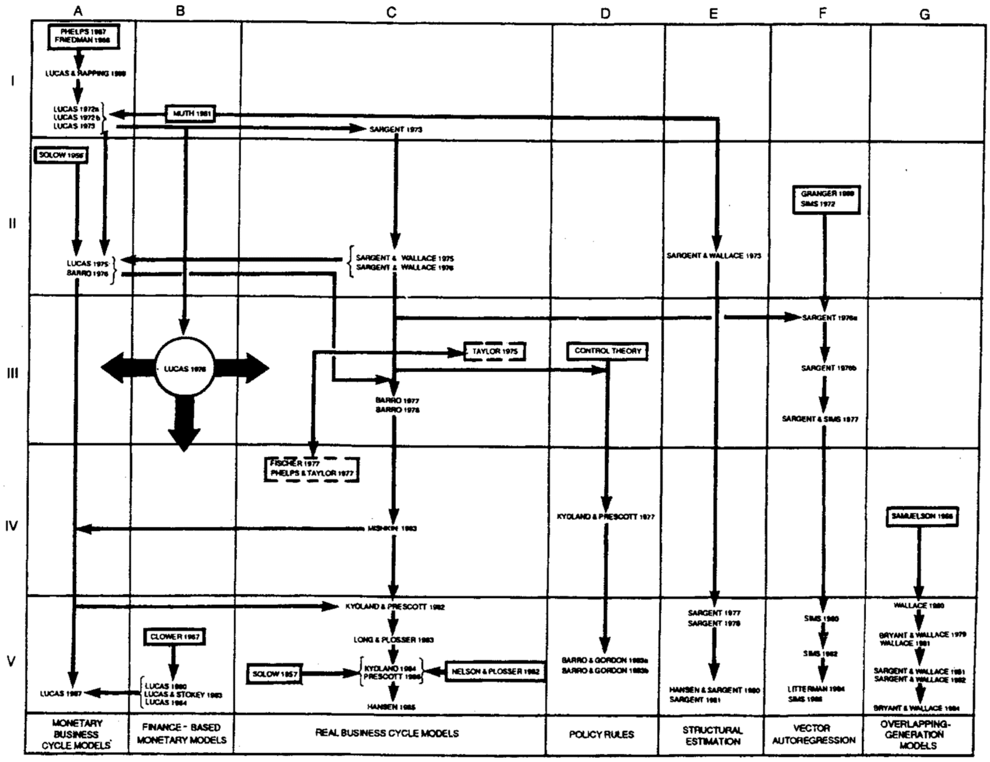

Figure 4.1: A table of kinship and consanguinity for the new classical macroeconomics (from Hoover 1991, 377).

The second project is from François Claveau and Yves Gingras (2016). They wanted to study the evolution of specialties in economics from the late 1950s up to today. To do so, they relied extensively on SNA. They did not use the technique of graphically representing the initial networks constructed to perform their analysis because these representations would have led to the infamous hairballs mentioned before – see Figure 4.2 for a graphical representation of the network of articles published between 1991 and 1995 in economics.

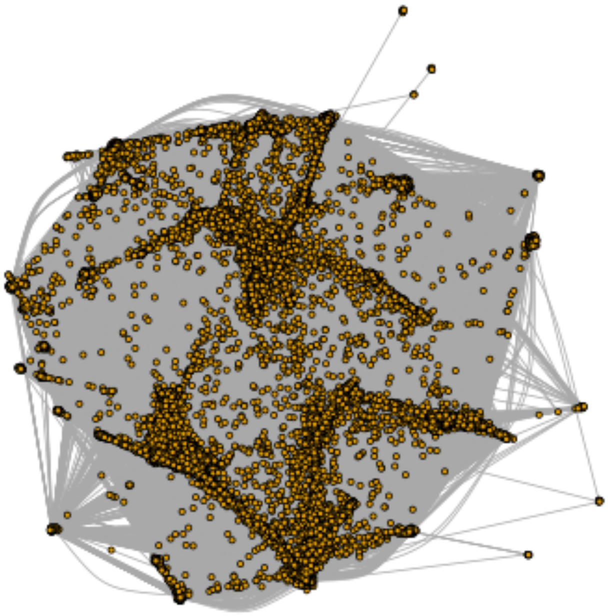

Figure 4.2: 'Hairball' network of articles (n = 32,903) for time window 1991-1995 from the project by Claveau and Gingras (2016). The nodes are the articles published in the time window and the edges are given by the method of bibliographic coupling (described in the main text). The researchers refrained from disseminating such network representations because they are uninformative.

The first point of contrast between these two studies is their informational bases from economics. In the case of Hoover, the information that he relied on in the construction of the network is heterogeneous both in source and in format. The researcher knew a lot about new classical macroeconomics from being trained in economics and from participating in debates in macroeconomics (Hoover 1988). This knowledge was coupled with a close reading of published material, especially of who cites whom and for what purposes. In contrast, the main informational basis used by Claveau and Gingras is more homogeneous: the list of references from around 400,000 articles published in economic journals indexed in the Web of Science database. In this database, each article has an identifier and each reference was given another identifier that tracks when a document appears in the bibliographies of two (or more) articles. Figure 3 illustrates what this primary informational basis looks like by reporting the first ten lines out of the 10,4 million lines of the table of references they used.

	ID_Art	ID_ref
1:	557	3855165
2:	557	175609
3:	557	182313
4:	557	133847
5:	557	169533
6:	557	177021
7:	557	176767
8:	558	1054416
9:	558	1057003
10:	558	179571

Figure 4.3: The first ten lines of the table of 10,4 million references used by Claveau and Gingras (2016) as their main informational basis. 'ID_Art' is the identifier of the *citing* article. 'ID_ref' is the identifier of the *cited* document. From the extract, we see that the article with id 557 cites seven documents.

This table is the main informational basis of their SNA, but it is not the only information that Claveau and Gingras relied on (see Section 3 for the role of historical knowledge in their corpus selection). Yet, the crucial point in contrast to Hoover's project is that they did not build the network to effectively convey knowledge that they already possessed; they built the network to learn about the relational structure.

The second point of contrast between the two studies is the characteristics of the nodes and edges, the two building blocks of networks. Hoover's study allows for quite some *selectivity* and *heterogeneity* in picking out nodes and edges. He tells us that the nodes are "[f]or the most part […] particular papers that were important in the development of new classical doctrine" (Hoover 1991, 376). They were selected to be "exemplars of the main lines of new classical thinking" (*ibid.*). Nodes are also heterogeneous. They are sometimes made of more than one paper or even represent whole fields such as, for example, 'control theory'; they are also represented by rectangles if they are "outside the new classical macroeconomics" (Hoover 1990, 376).

Selectivity and heterogeneity also hold for directed edges in Hoover's network representation. Hoover did not attempt "to reproduce the full and complex interrelationships between the exemplars listed", for instance omitting links "when it would have overly cluttered the diagram" (*ibid.*, endnote 22). We also have various types of arrows: some point to other nodes, some point to other arrows and yet others are larger and simply point in a direction (i.e., the ones departing from Lucas 1976, see Figure 4.1).

All these choices can be justified given that the purpose of the network representation is to effectively convey a wealth of information. It is easy to imagine Hoover engaged in a trial-and-error process to find the layout that struck the appropriate balance between being exhaustive and being readable. He already had the knowledge contained in the representation beforehand.

In contrast, Claveau and Gingras produced a network in order to apply computational tools. This purpose constrained their freedom regarding their selectivity and the heterogeneity of nodes and edges. In their network, each node stands for an article in their corpus. The only reason they find to exclude 8 articles (out of 400,000) is that these few articles "have vastly more references than the others". Here, selectivity is only based on technical considerations relative to discovery, such as that they did not want the results "to be driven by these few peculiar papers" (Claveau/Gingras 2016, 560). The same properties hold for edges. They were built using the method known as bibliographic coupling: the strength of the edge between two articles is proportional to the extent to which their references overlap. Figure 4.4 illustrates how an edge with a weight of 4/7 between two hypothetical documents is constructed using bibliographic coupling.[6]

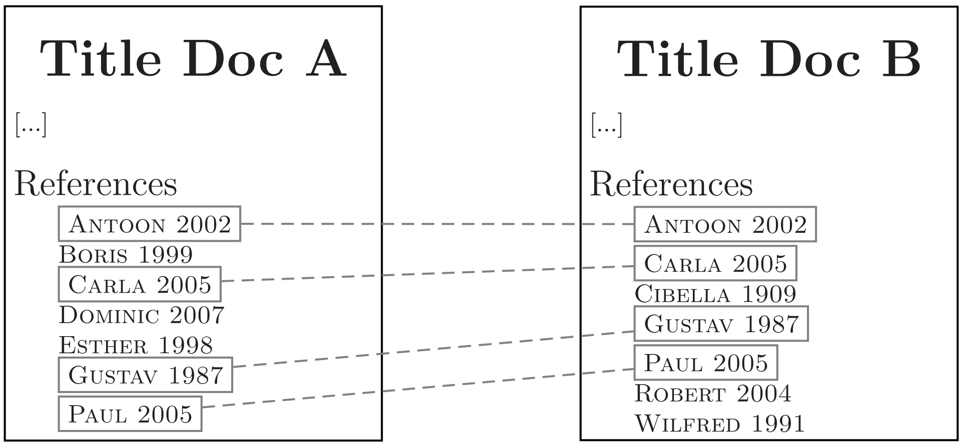

Figure 4.4: Illustration of the method of bibliographic coupling between documents A and B (figure from Claveau/Gingras 2016, 557). It shows two documents with seven references each. The four references they share are highlighted. The cosine measure that is used to give the weight to the edge between A and B is calculated as 4 divided by the square root of (7 x 7), or 4/7.

Although Hoover also considered citations to identify his relations of kinship, a noteworthy difference with the use of citations in Claveau and Gingras's project is that Hoover's close reading of the documents allowed him to distinguish citations serving different functions – for instance, citations to criticize or to praise some other research. In Claveau and Gingras's

[6] Networks can have weighted edges, which capture the intensity or tightness of a relation, and not only the fact that a relation exists.

project all citations are treated equally. This difference illustrates how SNA, especially when it is used on large corpora, compels researchers to leave out potentially relevant information.

A third contrast between the two research projects is in the production of the network. While Hoover has used tacit knowledge to converge on a representation conveying information efficiently, the production of the networks in Claveau and Gingras's project was a matter of instructing the computer to transform the table of references (as in Figure 4.3) into an 'edge list' – that is a table with one line per edge – by calculating the strengths of connections using bibliographic coupling. Figure 4.5 gives the first ten lines of their edge list (out of 123 million).

	Target	Source	Weight
1:	557	768555	0.07142857
2:	557	43126104	0.07881104
3:	558	64116	0.09128709
4:	558	567983	0.16269784
5:	558	801489	0.22360680
6:	558	802025	0.15811388
7:	558	2401596	0.05590170
8:	686	704	0.12734291
9:	686	3846	0.04956816
10:	686	235569	0.02398006

Figure 4.5: The first ten lines of the edge list produced by Claveau and Gingras (2016). The first two columns ('Target' and 'Source') give the identifiers of the articles that are connected (the 'ID_Art' of Figure 4.3) and the last column gives the strength of the connection (using bibliographic coupling, see Figure 4.4).

The last point of contrast concerns how the network is used. This is the most important one. Hoover (1991, 376) sets out to "investigate systematically the relations of kinship and consanguinity among the concrete exemplars of the new classical economics". His network representation is the main research output of this endeavor. The remaining task for him was to report "[t]he story told by the table" (ibid.), something that he does in less than a page and half.

In contrast, when Claveau and Gingras had produced their network (i.e., their edge list), they had nothing interesting to say yet. They needed to investigate structural properties of this network. Many properties can be studied. Which ones are relevant depends on the question asked. Since they wanted to investigate how economics as a discipline is divided into specialties, Claveau and Gingras opted for what is called 'community detection': an automated technique to partition the nodes such that each 'community' is made of relatively tightly connected nodes in comparison to the overall degree of connectedness in the network. In other words, the clusters created are made of articles that tend to cite the same documents more than average. When they had these clusters, they used a text mining technique to find automatically generated keywords that characterize each cluster. They also used other techniques of discovery (see Claveau/Gingras 2016, sections 4-5), but let us limit ourselves to these two. With these techniques they uncovered a structure of specialties that they did not previously know about.

Although they had prior beliefs about some main trends, divisions and schools of thought in economics, what they uncovered is not a map of these beliefs, but some patterns in the data. The specialty structure that they uncovered can be displayed as network representations in a much more informative way than their initial hairball networks. Figure 4.6 represents the uncovered structure for the period from 1991 to 1995 (the same as in Figure 4.2). Each node now represents one cluster (not an article) and each cluster is named with the automatically generated keywords labeling the specialty. The identity and size of a cluster as well as the relationships between clusters inform us about the state of economics in the early 1990s. For instance, we can recognize fields such as development and labor economics, and we see that the smallest community is more tilted toward historical considerations and Keynesianism. Claveau and Gingras also produced another representation of the specialty structure as a timeline over the full period covered by the study, i.e., 1956 to 2014 (see the web application of this project at: DigitalHistoryofScience.org/Economics/).

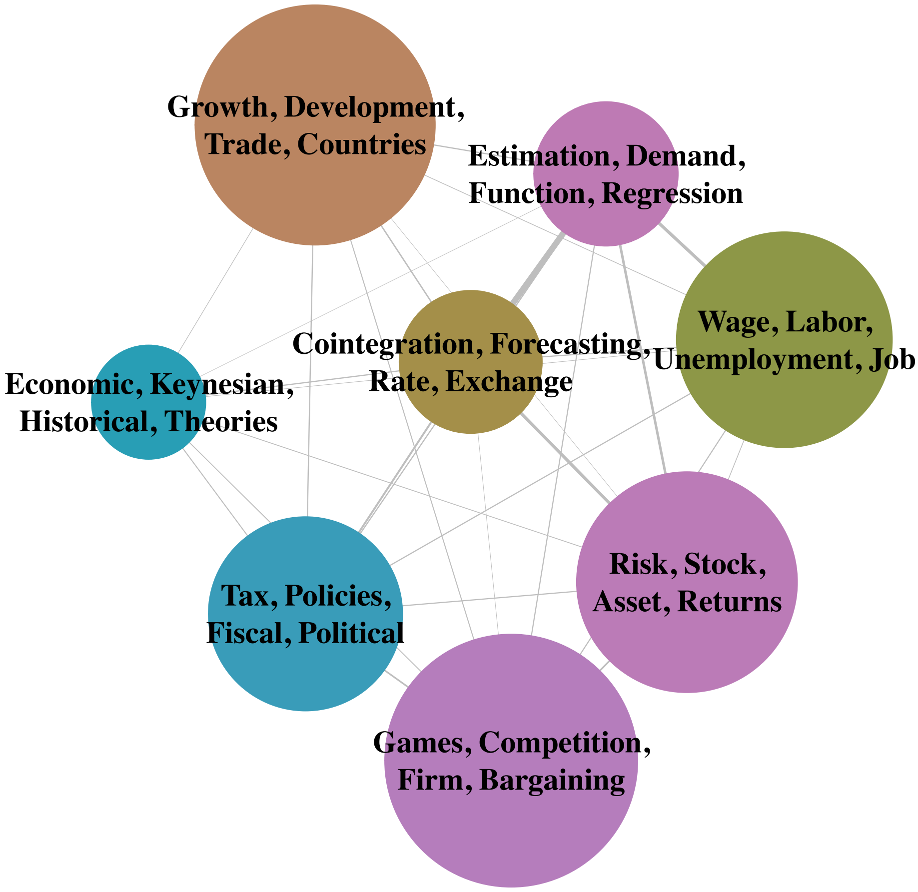

Figure 4.6: Network of economics in window 1991-1995 (from Claveau/Gingras 2016). The size of a node represents the relative share of documents in the time window. The thickness of edges and the distance between nodes give a rough indication of the proximity of clusters in terms of proportion of shared references. Keywords are algorithmically extracted from the data.

Both studies discussed ended up producing network representations, but the role of the 'network' in each was markedly different. Hoover built a graphical representation of a relational structure that illustrates kinship relationships in the new classical macroeconomics. He created this representation from a heterogeneous informational basis. He produced his network representation as a means to effectively convey what he had learned from his study of this school of thought. In contrast, Claveau and Gingras built a network from a standardized source (i.e., indexed references). Their initial network was not a graphical representation, but only a list of weighted edges. On this mathematical object, they applied techniques for discovering structural properties from SNA. Ultimately, they produced network representations to convey parts of their results. But what makes their study a case of SNA is the use of methods of discovery on a network structure, rather than the inclusion in their published output of figures like Figure 4.6. Contrasting both project not only illustrates that they use distinct approaches. It also illustrates how SNA can be a new and highly valuable approach to make new *discoveries* in the history of economics.[7]

3. Network Analysis as a Method Complementing Traditional Historiographical Methods

In this section, we argue that while SNA can be a useful method for the history of economics, its appropriate use requires more than knowledge of the techniques. Conducting a SNA involves several steps and historical knowledge of economics will be necessary at least at some of these steps. More specifically, we argue that when applied in history, SNA often has to be complemented by traditional historiographical methods in order to generate meaningful results. Traditional methods, such as text analysis, hermeneutic approaches, and source criticism, for example, can be required to generate such historical background knowledge. This point is not new. It relates back to a debate in history and historiography about the usefulness and relevance of quantitative methods, statistical methods in particular, in history that took place in the 1960s and 1970s (see, e.g., Düring/Kerschbaumer 2016, Fogel 1975, Tilly 1973, 2004). This debate – while less forceful in tone today – still influences the current discussion about the usefulness, the purpose, and the limitations of SNA in history more generally (Düring/Kerschbaumer 2016). One argument often raised in this debate is that quantitative methods should be complemented by qualitative historical research rather than replace it. We argue that this also applies to SNA.

What does it concretely mean that SNA should be informed by historical background knowledge generated by applying more traditional methods? We answer this question by tracing the different steps of analysis that are generally involved in an application of SNA in the history of economics. Historical background knowledge is always needed at least at some of these steps and sometimes even at all of them. When needed, it influences the results via the methodological and conceptual choices the researcher has to make. This is one sense, so we argue, in which SNA should be viewed as a method that complements rather than replaces more established approaches in the history of economics.

What are generally the different steps involved in a SNA that get us from the identification of a historical event, object, or process that we want to investigate to the final research results? We can roughly identify the following six steps: The researcher begins by (1) *choosing an object of study*, such as a historical event or process, and *formulating a research question* that

[7] A similar point could have been made about SNA as a method of confirmation (rather than discovery) if, instead of using a primarily inductive approach as Claveau and Gingras do, one of the few existing SNA in the history of economics would have started with a hypothesis to be tested.

allows us to learn something about that event, object, or process. In order to answer the research question, the researcher then has to (2) *select the historical sources* he or she is going to use. Source selection involves an assessment of the quality of the sources that are used in the analysis. It is closely connected to (3) the *specification of the network boundary*. In order to analyze historical sources with quantitative methods, the researcher then has to (4) *process the historical sources* in a particular way. This act of processing can involve transforming historical sources into quantitative data. To analyze the resulting data with tools from SNA, the researcher typically (5) *generates a network representation* that combines the data in a particular way. This visualization of the network is a step that is in principle not required when conducting a network analysis but it sometimes allows, among other things, for a fruitful exploration of the data. The researcher subsequently (6) *analyzes the network (i.e., the data)*, oftentimes in an exploratory fashion and in a trial-and-error way. It is here where the role of SNA as a method of discovery and confirmation becomes prevalent. At this step, the results are quantitatively and/or qualitatively presented and they are *interpreted.* The interpretation of the results will usually involve re-contextualizing the obtained results, i.e., interpreting them in light of existing historical narratives and – importantly – in light of the historical sources that grounded the network analysis in the first place.

In the following, we look at each of those steps in turn. Not all steps look alike across the full spectrum of SNA and thus, not every SNA has the same demands with respect to historical knowledge. There are network analyses that involve large bibliometric data sets and are based upon complex computational and statistical analyses, such as Claveau and Gringas (2016) or Herfeld and Doehne (2018). And there are those, which are computationally and statistically less demanding, are grounded upon a small set of relational data, and involve only basic statistical analyses, such as for example Herfeld (ms) and Wright (2016). Both types of analyses are valuable and the difference between them is one of degree, not of kind. Because both ultimately rely upon tools from SNA to analyze quantitative data, they count as methods of discovery and confirmation in the aforementioned sense. But as they differ in the details of the research process, the kind and extent of historical background knowledge needed also differ. We should therefore keep in mind that the following points do not categorically apply in the same way to all network analyses. However, by discussing each of the steps in turn, we see how SNA at several steps is complemented by more traditional methods and that it frequently requires background knowledge about the particular historical period or process.[8]

[8] Note that those six steps do not necessarily occur in a perfect sequence when conducting the analysis – they can overlap.

Step 1: The Object of Study and the Formulation of Research Questions

Serious research starts with selecting a relevant object of study and formulating a sound research question. This is a platitude that is worth repeating in the case of SNA because, much like for other methods, we run the risk that the method takes precedence. As the motto goes: "When you get your first hammer, everything looks like a nail." The methodologically sound recommendation is that the topic and the question must be selected first. Since SNA lends itself to answering some questions but not others, its relevance and usefulness as a method cannot be assumed a priori.

While SNA can be meaningfully applied to study different kinds of relations (e.g., memberships, family relations, exchange relations, competition relationships, relations between research fields), research questions that do not ask for the analysis of relations at all will not be meaningfully answered by SNA. Furthermore, the quantitative-empirical tools of SNA require a significant reduction in the complexity of the relations studied and thus in the characterization of a social situation or a historical context. SNA (as probably any other method) cannot capture a social situation in all its complexity (see also Bixler et al. 2016). If a specific object of study should be analyzed in its full "thickness," interpretive methods will be more appropriate than SNA alone. Text analysis or oral history interviews, for example, allow for revealing the nuances and ambiguities of a social relation. Hermeneutic approaches are often justified precisely because they capture ambiguities in the meaning of a text that, for instance, implicitly or explicitly describes a social relation (Düring/Kerschbaumer 2016, 35 ff.). In contrast, abstracting from much detail is an essential part of SNA. In short, a useful SNA takes into account that a network only represents specific aspects of social reality and that it furthermore cannot capture the nuances underlying specific relations.

Both aspects, the danger of applying SNA to everything and its demand for abstraction, ask for particular care when choosing the object of study and formulating research questions. Questions that experienced network analysts pose are often very specific, are adapted to the limited scope of the analysis, and are explicit about what can and cannot be shown (Bixler et al. 2016, 104). Researchers often target concrete issues, such as the manifestation of particular social structures, interactions among particular groups of people, the distribution and exchange of specific resources, the identification of roles and positions in a defined social network, social interdependencies among historical actors or within groups, institutional hierarchies, or questions that target the relation between a specific network structure and the level of individual actions (ibid.). Choosing an object of study and formulating a research question also require that the researcher anticipates the set of abstractions made in the process that will imply neglecting certain aspects of the phenomenon in the analysis. Both requires a certain level of awareness about, and sensitivity towards, what can and cannot be lost of the 'thickness' of the historical context.

To take an example, the research question of Claveau and Gingras (2016, 552) is meant to make a contribution to historical knowledge, but at a large scale and not in any detail. They ask "how specialties [in economics] have emerged, grown in relation to each other, and (for some of them) disappeared" from the late 1950s to the early 2010s (Claveau/Gingras 2016, 552). They justify their question by noting the recent growth of economics as a discipline and how our "grasp [of] the global structure and morphology" of the discipline is as such limited (ibid.). To them, the history of recent economics would not cover all the relevant perspectives if historians were solely focused on studying a selective set of social contexts, highly influential economists, approaches, subfields, or economic ideas. They consider discovering and studying properties of the macro-level dynamics of economics as a field to be equally important, but not to be a substitute to more micro-level historical studies. The former suggests a SNA, while the latter would benefit from more detailed and qualitative historical approaches.

This example already indicates that, although it is a case of a SNA extremely reliant on computational methods, prior historical knowledge is necessary at this first step. To argue for the relevance of their research question, Claveau and Gingras needed knowledge about the social structure of economics as a field and how it has changed over time. In general, selecting an object of study and a research question presupposes answering a set of methodological and conceptual questions, such as: 1) What will the network consist of?; 2) To what extent do the categories that will be used in the analysis (e.g., categorizing something as a node or as an edge, and determining the properties of an edge) capture the relevant parts of the phenomenon?; and: 3) Can the research question be adequately addressed with the anticipated categories? (see also Düring et al. 2016, 173). Answering those questions requires historical knowledge about the object of study to make an informed decision about what can be abstracted from without losing essential historical aspects that are required for the analysis. Furthermore, the researcher has to be clear about the relevant ambiguities that characterize a set of relationships in a particular group and why we can abstract from them. Only then, a SNA can be informative and offer an improved understanding about the subject matter.

Step 2: Selection of Sources

The second step in conducting a SNA involves the selection of sources that help answering the question and are appropriate for the analysis. Some SNA use existing bibliometric databases (e.g., Gingras/Claveau 2016). Other research projects have to extract relational data from historical sources, for example written reports, letters, or other kind of archival material that is text-based (e.g., Herfeld ms., Wright 2016). Historians must select the sources based primarily on relevance, reliability, and ease of access and treatment. Prior historical knowledge or knowledge of other research methods play a role in this assessment.

A major informational basis for SNA in the history of science is bibliometric databases. For example, Claveau and Gingras (2016) use Web of Science and Herfeld and Doehne (2018) use Scopus. The assumption that these sources are acceptable is supported by knowledge about the composition of the databases and by prior knowledge about the aspects of science that the researchers study. For instance, it is well known that Web of Science indexes only what its staff takes to be the "the major academic journals around the world" (Claveau/Gingras 2016, 551) and that it is therefore mainly constituted by English publications. If Claveau and Gingras wanted to cover research at the fringe of economics, Web of Science would be a bad choice. In contrast, they want to map mainstream economics and know that researchers based in the United States have dominated the discipline since the Second World War. Herfeld and Doehne (2018, sect. 5) offer a lengthier justification for drawing on Scopus because they use, perhaps counterintuitively, publications from 1984 to 2014 to study the diffusion of some scientific innovations from 1944 to 1970. On the face of it, this choice seems to be dictated by the poor coverage of Scopus prior to 1984. Yet, they argue that using *published articles* between 1944 and 1970 to study the diffusion process would be inappropriate because knowledge diffusion also "proceeds through working papers and other formats that are not systematically included in citation databases" (Herfeld and Doehne 2018). Again, this claim rests on prior knowledge of the workings of economics in the period of interest.

In contrast to this reliance on already existing databases, some SNA in history rely on relational data that are generated from primary historical sources, which oftentimes comes down to text material of some sort. How to transform this material into a data format appropriate for SNA is not always evident. This is one reason why the researcher will have to decide which sources will do. Some text material contains *explicit* descriptions or other information about interactions or other kinds of relations among entities. This sort of material might appear evidently suitable for SNA. Yet, rarely were the primary sources produced with the goal of performing a SNA; oral history interviews are one example. In consequence, the researcher must assess whether the systematic extraction of relational information from these sources is *useful and feasible*. For example, Herfeld (ms.) studies cross-disciplinary interaction, the spread of methods, and the exchange of information at the Center for Advanced Study in the Behavioral Sciences at Stanford University (CASBS). She decided to draw upon source material consisting of self-reported scholarly interactions and social exchanges among a cohort of fellows. More specifically, she uses a set of feedback reports of all members of that cohort as sources in which each researcher retrospectively reflected upon their social engagement during their visit. Fellows verbally stated and interpreted their social interactions and relations with other fellows in different ways. To select those reports as suitable for SNA, Herfeld had to interpret the reports, identify the various kinds of relationships those reports contain and decide whether they could be quantified. In short, she needed additional interpretive skills to select those sources as appropriate for the analysis.

Historians also use text material and other historical sources that contain only *implicit* information about relations (for an example of how relational data about illegal helping networks in the German National Socialism is extracted from autobiographical narratives, see Düring 2015). To extract relational information from such historical sources, the demand on interpretive skills is even higher (Stark 2016, 155). In short, the historian embarking on such a project must master more traditional (qualitative) methods such as, for instance, textual interpretation and other hermeneutic approaches as well as source handling techniques (e.g., Emmett 2003).[9]

Step 3: Boundary Specification

A crucial step in SNA is taking a stance regarding what is called the "boundary specification problem" (Laumann et al. 1992; Knoke/Yang 2008, 28).[10] Which entities and relations present in the phenomenon of interest should be represented as nodes and edges in our network? When should we stop extending the list of entities and relations? The stakes should be obvious: if entities and nodes are added in a non-systematic way, the resulting network risks being a misleading model of the phenomenon of interest. There is a rich methodological literature offering approaches or strategies to solve the boundary specification problem (see Knoke/Yang 2008, chapter 2). In what follows, we will only substantiate our claim that solving this problem requires some prior historical knowledge or some knowledge of non-SNA historical methods.

Take the two projects mentioned in the previous step to exemplify research relying on bibliometric databases. After selecting Web of Science or Scopus as the informational source, the next question is what inside these enormous databases should be used to construct the

[9] For a discussion of applying hermeneutic methods in the history of economics, see Emmett (2003).
[10] This step can be analytically distinguished from the previous step of source selection, but the temporal order of these two steps is rarely neat.

network. Claveau and Gingras (2016, technical appendix, Section 1.1) had to use prior knowledge of economics to select only economic journals. More specifically, they started from a classification of journals from the US-based National Science Foundation to construct their economics corpus. Since they knew that this classification is rather restrictive, they added some journals to their corpus that are at the frontier of economics and other fields (e.g., finance) by devising an inclusion procedure using a set of keywords. This procedure could not have been devised without some prior knowledge of the relevant keywords.

Herfeld and Doehne (2018) study the diffusion of rational choice theories across the social and behavioral sciences as a case of the diffusion of a scientific innovation across scientific fields. They sampled Scopus by starting from publications that cite the *Theory of Games and Economic Behavior* by John von Neumann and Oskar Morgenstern in the period between 1984 and 2014. To justify this choice of starting point, they argued that the *Theory of Games* contains the conceptual and theoretical innovations that laid the grounds for rational choice theories in the second half of the 20th century. From the identified publications, they then extracted all references to contributions published in their period of interest, i.e. 1944 to 1970, to finally link publications that were referenced together (i.e., co-cited) at least three times. This allowed them to capture the spread of the innovation. This procedure and its justification required prior knowledge about the history of rational choice theories.

Both of these examples are instances of the "nominalist" strategy to solving the boundary specification problem. Laumann et al. (1992, 69) defined this strategy as the self-conscious imposition by the researcher of "a conceptual framework constructed to serve his or her own analytic purposes." This strategy contrasts with the "realist" strategy, where "the network is treated as a social fact only in that it is consciously experienced as such by the actors composing it." (Laumann et al. 1992, 65) Although the labels used are far from optimal,[11] the underlying distinction is helpful. Indeed, a researcher could decide that two individuals are included as nodes in her network without these individuals being aware of belonging to a specific relational structure.

The point we want to make with this distinction between two strategies is that, to be properly used, the strategies both require knowledge of historical facts or historical methods. Consider the closely connected group of scholars that during the 1940s and 1950s collaborated at institutions such as the RAND Corporation, the Cowles Commission, or the CASBS (e.g.,

[11] Indeed, Laumann et al. (1992, 66fn) states in the footnote right after introducing their distinction that what they call "nominalist" is called "realist" by another scholar.

Düppe/Weintraub 2014, Erickson et al. 2013, Herfeld ms., Klein 2016). Imagine that we want to extract networks based on disciplinary identity among this group of scholars – e.g., having a network of psychologists and a network of economists. Was Patrick Suppes a psychologist albeit working in formal philosophy and statistics? Were Kenneth Arrow and Leonid Hurwicz economists despite working on questions in mathematical statistics and political science? Using a nominalist strategy would require arguing for the relevance of a criterion, perhaps PhD training or rather main publication venues, to distinguish among researchers. The argument for the criterion will need to be based on prior historical knowledge – for instance, about the relative heterogeneity and influence of PhD training at the time. A realist strategy, in contrast, demands to find the disciplinary self-identification of. This task faces the usual pitfalls of self-reported information in history, for instance of written autobiographies, interviews and questionnaires. Indeed, memory loss and other potential biases imply that such information cannot be taken at face value (e.g., Hoddeson 2006, Moggridge 2003, 59f f., Weintraub 2005; Bernard et al. 1982). More importantly, however, no matter which strategy we apply, background knowledge is required to justify one's conceptual and methodological choices.

Step 4: Processing the Sources

SNA requires strict data formats. Every network is made of nodes connected by edges. The historical sources do not come in this format. They need to be processed. This processing can sometimes be quite substantial, depending on how far one goes back in time and depending on the kind and quality of the sources. The processing of historical sources might lead to the previously highlighted reduction of complexity and often also to a neglect of ambivalence contained in the historical sources. Furthermore, offering a systematic data set for a clearly defined population frequently necessitates the extensive interpretation of those sources. To do that, the historian has to draw on methods such as textual analysis (if the sources are written texts) and other hermeneutic approaches to text interpretation. He has to be skilled in historical source reading and construction. This, of course, presupposes extensive historical knowledge.

Note, however, that the amount of ingenuity and historical knowledge needed to get the nodes and the edges vary significantly. Consider the network in Herfeld and Doehne (2018). It is built from bibliometric data and constructed to apply computational tools to it.[12]. Once they had decided how to set the boundary of their network, its actual construction was primarily a

[12] In these respects, it is similar to the SNA of Claveau and Gingras (2016) extensively discussed in the Section 2.

technical endeavor: each node stands for some scholarly contribution (e.g., articles, books, working papers) in their corpus and each edge stands for a co-citation of two articles. Articles are excluded from the analysis on the basis of a set of rules, such as their number of co-citations or their publication date. There was no publication excluded on idiosyncratic grounds. Selectivity is only based on rule-based technical considerations relative to discovery. Edges are similarly homogeneous and not selected. They were built via co-citation in the database.

Yet, as we saw in the previous steps, SNA using bibliometric databases do not exhaust the possibilities of SNA in the history of economics. In analyses using primary sources, there is typically much more work involved in processing the sources. The historian must formulate sharp categories for the entities and their relations although the primary sources are a lot less structured than a bibliometric database. Herfeld (ms.) for example produces nodes and their edges largely by coding the relations she extracts from text material using a pre-determined categorization of relations (e.g., colleague, friend, co-author, etc.). The network thus created can subsequently be analyzed with statistical tools. Here, source processing requires more historical background knowledge than in the previous example. Deciding on a meaningful taxonomy and undertaking this categorization of nodes and edges necessitate – again – a careful interpretation of the historical sources as well as drawing adequate inferences about possible hidden relationships.

It can be considerably more difficult to extract data suitable for a SNA from texts that have even less structure than the reports used by Herfeld (ms.); examples would be a prose text containing an autobiographical narrative, diary entries, or personal letters. In these cases, the network analyst must combine specialized interpretive skills with the rigor of formal data analysis to systematize text interpretation. In sum, we see that, at the step of processing the historical sources, the centrality of prior knowledge of history and of interpretive methods varies significantly across instances of SNA.

Step 5: Generating a Network Representation

Network analysts often recur to network representations as a first step towards the data analysis. However, as indicated in Section 2, an early visualization is not necessary. In the case of Claveau and Gingras (2016), the resulting hairball representations (see Figure 4.2) would not have been particularly insightful. Such network representations are only helpful if they reveal hidden and complex patterns of social relations in the data that we could not have easily seen by, for instance, reading the text material alone. Those patterns are often easier to detect via a network representation than when applying more traditional methods to a set of sources. This is simply because the data can be visualized in ways that highlight specific structural characteristics of a network while downplaying others systematically. If we attempt a graphical representation, we have to choose various aspects such as the placement of nodes in space (typically handled by a layout algorithm) and which information to convey through node size, shape, and/or color (as well as edge thickness and color), which set of nodes and edges should be included in the representation, and which of their attributes matter, among other things.

There are at least three goals of visualization (see also Düring/Kerschbaumer 2016). First, it gives the researcher an initial orientation in analyzing relational data. It can point towards interesting properties of the network. For example, exploring their clustered network via visualization, Herfeld and Doehne realized from the graph that not only the clusters but also the connection between clusters were relevant for the spread of rational choice theories. This inspired a typology of roles they introduced to theoretically account for this connection (see Herfeld/Doehne 2018, Table 4).[13] Second, it can help the researcher generate hypotheses that can then be tested by way of a more complex SNA or through other historical methods. For example, in Herfeld and Doehne (2018), the existence of relations between clusters lead to formulating hypotheses about the relationship between different sub-disciplines towards which rational choice theories spread and the conditions in place for such a cross-disciplinary spread to occur. Third, a network representation can establish a basis for assessing the face validity of the network – e.g., whether some major coding errors have been made (Düring/Kerschbaumer 2016, 38). With respect to all three goals, a network representation abstracts from a large amount of historical detail. Its function is comparable to that of a map guiding the researcher by reducing details that are not relevant to the research question at hand. However, as with city maps, while they guide you in places that you have never been to, you must still be able to interpret and relate the signs around you to the symbols used in the map to read it and understand where the nearest highway, restaurant, pedestrian walkway, lake, or river is.

Step 6: Network Analysis and Interpretation of Results

As mentioned before, one of the most important steps in a SNA is to analyze the properties of the network. Such analyses can be based on network representations but do not have to. Most of the time, they are executed on the underlying matrix containing the network relations (e.g., Düring/Kerschbaumer 2016, 39, Knoke/Yang 2008, 45). The choice of techniques for

[13] This is not to say that in their analysis, Herfeld and Doehne would not have detected those connections and their relevance without the representation but it certainly helped.

analyzing networks should be motivated by the research question or the hypothesis. Techniques for quantitative analysis include, among others, positional measures (such as different metrics of network centrality as well as similarity and equivalence measures) and clustering algorithms. Choosing among them requires both technical expertise for their application and an understanding of the underlying computation procedures, that is, knowledge about what it is those techniques actually do when applied. However, it also requires an understanding of which of the many techniques available will address the research question at hand. We can ask, for instance, what the hierarchical structure within the Cowles Commission during the 1940s and 1950s was. To find an answer to this question requires the choice of techniques and measures that will help us to discover structural properties in the data that represent this hierarchy.

Once results are produced, they must be interpreted. It is probably the part of the analysis where the need for historical background knowledge is most obvious. The interpretation of the results will often involve re-contextualizing them historically, i.e., interpreting them in light of existing historical narratives and – importantly – in light of the historical sources that grounded the SNA in the first place. In the case of small-sample SNA based upon textual sources, this typically means a return to the primary sources. For example, the network connecting scholars on the basis of their interaction during their year at the CASBS was interpreted by Herfeld (ms.) as a network of information flows and of tools exchange. This required not only to go back to the written reports in which the fellows described the kind of relationship and the kind of information and tools they exchanged during their fellowship year. Additional archival material and other textual evidence about, for example, the specific social context of the CASBS helped to understand characteristics of interactions between scholars at the CASBS. Reconnecting the abstract network analysis with the historical sources might even involve an act of re-interpretation either of the sources or of the network analysis.

What a historical interpretation amounts to is far too complex to be tackled here (see Emmett 2003, for an overview with a focus on the history of economics). But we want to note that historical knowledge is extremely important in the interpretation of results generated by a SNA. Any historical interpretation – and thus also of the results of a SNA – has to be based on considerations about the meaning that gives particular events their historical significance. This is in part a constructive activity. To identify the meaning and thus the significance of a historical event, the historian must decide, among other things, which events – and the results thereof – to focus on and how those events are to be connected. She must decide on categories and concepts that capture this meaning to describe the results of the analysis (e.g., is a series of events best described as a scientific revolution, a methodological turn, or a shift towards new problems?). The implication of all this for SNA in the history of economics is that, at the step of interpreting the results, the researcher must have extensive historical background knowledge and the necessary expertise to use interpretative methods.

4. Some Advantages of Network Analysis in HET

The advantages of using network analysis in HET appear obvious to us.[14] First, network analysis can reveal stable patterns that would be difficult to recognize in a systematic way when studied only by more traditional methods. Exemplary analyses such as by Claveau and Gringas (2016) show how empirical algorithmic procedures can be used to reveal and systematically study non-trivial hidden structures in networks. With the increasing availability of new source materials from personal and institutional archives such as syllabi, personal and professional correspondence, institutional records, etc. (Weintraub 2017, 149, Weintraub et al. 1998), SNA can more easily be put to the task of finding and studying these patterns.

Second, SNA offers a distinct perspective in answering the questions of historians of economics. It puts into focus the relational aspect of scientific activity (e.g., Emirbayer 1997). We can liken it to a powerful instrument to study relational structures by allowing "us to draw or to measure, the equivalent of a microscope or periscope" (Lemercier 2015, 4). This perspective, the specific data on which it relies, and the results it generates can be used to assess historical claims arrived at by other methods.

Third, SNA can be used to analyze large data sets. Studying the evolution of economics as composed of multiple specialties (Claveau/Gringas 2016) or the spread of rational choice theories across all the behavioral and social sciences (Herfeld/Doehne 2018) would confront serious challenges when studied only by traditional – qualitative – historical approaches because of the sheer scope of the phenomena. SNA and other bibliometric methods allow the historian of economics to broaden the scope of her research.

Fourth, SNA can mitigate confirmation bias, which is a bias to which historical research is often prone. An appropriate quantitative research design forces the researcher to be explicit about the rule-based assumptions underlying the construction of the network. Furthermore, the actual compilation and analysis of empirical networks is preceded by a systematic process of evidence gathering in the course of which the researcher's attention is turned also to relations that seem improbable at face value. Whenever a constructed network reveals the

[14] For a set of similar arguments, see also Doehne/Herfeld (ms.).

presence of unexpected relations (or an absence of expected ones), the historian can search for explanations of the result and whether this may have affected the postulated events.

Finally, historians of recent economics should seriously consider using SNA to follow changes in the way economists study the economy. In recent decades, there has been a shift in economics away from great ideas and general theories by important thinkers – e.g., Adam Smith, Karl Marx, John Maynard Keynes – or major schools of thought – e.g., Keynesian macroeconomics and monetarism – towards the development and application of models, of a variety of mathematical, statistical and empirical tools, and the pursuit of different scientific and policy-oriented practices (e.g., Fontaine 2016, Schabas 1992, Weintraub 1999, 2017). This shift led historians of economics to complement the history of ideas with a concentration also on contextualized histories of those methods, tools, and practices within their respective social, economic, cultural or political contexts. Applying SNA allows us to take a relational perspective on this period to reveal how the development and application of those methods, tools and practices has been crucially influenced by contextual factors.

Despite its usefulness, SNA – as we have argued – is not a substitute for other historical methods. Used alone, it makes for terse histories. The example on the specialty structure of economics is a case in point: this primarily algorithmic work only becomes insightful when its results are combined with narrative accounts of the recent history of economics or when it identifies “intriguing patterns that invite more in-depth, qualitative research” (Claveau/Gingras 2016, 552). SNA can also be implemented in unreasonable ways, especially when the desire to use the method takes precedence over the soundness of the research strategy. Indeed, SNA does not apply to all questions. Even questions that ask for an analysis of relations might not best be answered by SNA. This is because some questions can only be answered adequately by an approach that allows for a thick history and not by an analysis that demands – at least in a first step – a simplification of those relationships. SNA is thus a complement to other methods, bringing its specific strengths to the systematic study of relational structures in the history of economics.

Applying SNA in history of economics requires not only mastering the traditional set of methods that historians of economics have been using all along. It also requires of the historian of economics to acquaint him- or herself with a set of computational tools and computer programs to analyze relational data. We want to conclude by noting that while this might sound challenging, many tools are user friendly. Among the multitude of computer programs that have emerged in the last decades to conduct SNA, only some are useful to the historian (of economics). There are packages for beginners, packages for network representation, and a set of general-purpose programs. Two websites to find further information should be mentioned here. *Programming Historian* offers tutorials and instructions for some of the relevant software packages (see https://programminghistorian.org). *Historical Network Analysis* (see http://historicalnetworkresearch.org) provides a wide array of sources, such as an extensive bibliography on the use of SNA in history, links to software tools, tutorials, a list of events for historians applying SNA, among many other resources.

5. Conclusion

In this chapter, we discussed the usefulness and limitations of SNA as a method for the historian of economics. Our main argument was two-fold. First, we showed how SNA could serve not only as a tool for representation but foremost as a tool for discovery and confirmation. Second, the application of SNA requires historical knowledge at various steps in the analysis. At least in that sense, its meaningful application has to be complemented by more traditional approaches. We hope to have shown why historians of economics have reasons to add SNA to their toolbox. Being a method that helps us to discover hidden patterns in historical data, SNA can complement more traditional methods of the historian of economics.

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