One Sentence at a Time: A Quantitative History of Rationality in Economic Thought

ARTICLE HISTORY
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Abstract
This article demonstrates how unsupervised quantitative methods can enrich the history of economic thought. Using the largest English-language corpus ever assembled for the field—nearly 290,000 economics journal articles from 1900 to 2009 with citation data—we analyze the evolution of the concept of rationality. Combining large language model–based semantic analysis with bibliometric and network methods, we identify and cluster discussions of rationality across time and scales, such as the circulation of bounded rationality and the emergence of behavioral economics. We provide an open-source interactive tool to support transparency and reuse.

KEYWORDS
rationality; economics history; bibliometrics; behavioral economics; natural language processing; large language models

JEL CLASSIFICATION
B00; B20

Introduction

In the last decade, the number of history of economics papers employing quantitative methods has increased (see e.g., Goutsmedt, Claveau, and Herfeld 2023 special issue). Several essays have adopted a reflexive stance, examining the implications of using quantitative methods in the history of economics (Cherrier and Svorenčík 2018; Edwards, Giraud, and Schinckus 2018). These contributions have aimed to provide broad discussions on the use of such methods. However, given the virtually unlimited variety of quantitative approaches potentially relevant to historians of economics—and the wide array of research questions they can address—these reflections often remain abstract and offer little practical guidance. As a result, they tend to provide useful broad overviews, but without clearly articulating what quantification entails in practice, and how it can be both meaningful and challenging to integrate into research specific to the history and philosophy of economics.

Our contribution sits between a historical study that uses quantitative methods to answer a specific question and a general methodological discussion of those methods. From the

collection of data to the interpretation of results, we illustrate concretely how these methods are useful and examine, in practice, the methodological choices they entail. We present a step-by-step application of specific quantitative methods to a broad topic: the history of rationality in the twentieth century.

We focus our discussion on unsupervised methods that have been particularly influential in the history of economics. Unsupervised methods are machine-learning techniques in which algorithms identify patterns from unlabelled data, as opposed to supervised learning methods—such as regressions—that learn patterns from labelled data to make inferences. The goal of unsupervised methods is not necessarily to provide a "measure" (Grimmer, Roberts, and Stewart 2022)—though they can be adapted to do so—but to organise in categories large corpora and enable accelerated and "distant reading" (Moretti 2013; Guldi 2023). They are well suited to historical inquiry because their unsupervised nature reduces the risk of presentism: rather than imposing present-day categories on the past, unsupervised algorithms uncover patterns directly from the data. When time is explicitly incorporated, they allow researchers to map the discipline at different points of time, to identify the emergence and decline of subjects and concepts, and to assess the influence of specific economists or ideas.

Our article uses two types of data, texts and citations. The analysis of textual corpora offers a direct window into the semantic content of debates, while citation data provides a lens through which to view intellectual interconnections and channels of influence within the discipline. We show how a large corpus of documents can be classified based on the information contained in textual and citation data—what we call "semantic clusters" and "bibliometric communities."[1]

Above all, our discussion aims to illustrate a core principle for historical inquiry with such unsupervised quantitative methods. They require continuous back-and-forth between aggregate quantitative results, complementary indicators used for interpretation, and preliminary knowledge and close reading of primary and secondary sources. These methods function not only as a form of corroboration but also as "discovery methods" (Grimmer, Roberts, and Stewart 2022): they facilitate the exploration of large datasets to reveal historical patterns. They often confirm, and sometimes complement, established findings. They can also reveal pitfalls and blind spots in existing research.

The concept of "rationality" is an effective focus for a concrete demonstration. First, many historians of economics engage with it in one way or another, which makes the exercise relevant for a broad audience. Second, because the concept is broad and pervasive in economics, applying quantitative methods to a very large corpus is particularly informative.[2] We use a corpus of around 290 000 articles in economics extending back to 1900 to show how these methods can handle long time horizons. Third, the multiple meanings attached to "rationality" and its uses applied to various subjects show how textual methods, coupled with bibliometrics, can help capture this semantic plurality.

In what follows, we concentrate on what such a quantitative analysis requires in practice. We highlight what kinds of questions and challenges arise at each stage of the research process. This focus lets us highlight (a) the crucial issue of selecting sources and building data; (b) how even simple quantitative assessments can be informative; (c) the challenges and subjective choices involved in building and adapting tools; and (d) why interpreting results demands careful attention to various indicators and close knowledge of both the corpus and its historical context. By tracing, step by step, how we assemble and analyze our corpus, we aim to provide a practical example and a reflection on broader methodological issues faced by historians of economics in quantitative inquiries. The analysis of the results relies on the use of an

[1] The bibliometric communities, identified through network analysis, could also be called clusters. But we opted for "communities" in order to distinguish them from the "semantic clusters".

[2] To be clear, we don't think that quantitative methods are only helpful for very large corpora. However, it is where their surplus value may appear as the most obvious.

interactive application that we have built for this article.[3]

From sources to corpus

From sources to data

Discussions on quantitative methods often focus on the varieties of existing methods. In practice, however, analysis and interpretation come last. Most effort goes into collecting, cleaning, and structuring data, much of which remains invisible in published work. Sources rarely arrive as ready-to-use datasets; they must be transformed from somewhat raw materials into usable corpora. In short, the quantitative historian must be as much a data wrangler as a data analyst.

Bibliometric databases are a convenient way to access corpora of economic texts: they record relatively well-structured data, gathering key features of scientific output—such as authors, journals and affiliations, *etc.* Some of these databases, such as *Web of Science, OpenAlex,* or *Scopus,* record citation data, which enables tracing intellectual influence through diffusion patterns, and mapping scholarly contributions over time.

Each database has its own strengths and weaknesses. While at a very general level Web of Science, OpenAlex, or Scopus have similar coverage (Martín-Martín et al. 2021; Culbert et al. 2025), some studies might suffer from choosing a less appropriate database regarding the research questions. For instance, Scopus has a lower coverage of the top 5 economics journals before the 1990s and while being openaccess, OpenAlex has been less curated than the products of private publishers. Whatever the provider, less successful or now-defunct journals are also more likely to have incomplete or discontinuous digital coverage, impeding their inclusion for historical analyses. Additionally, databases are oriented toward English-speaking contributions; these databases may thus be deficient for a research project targeting another or multiple languages.[4] More generally, citation practices have only standardised progressively in the postwar period. Consequently, citation data are most of the time relatively poor before the 1960s. Last but not least, although they provide useful metadata and citation information, these databases generally lack full text, which is subject to copyright and therefore cannot be obtained from a single publisher.

Even when citations and full texts are available, the amount and quality of information that can be reliably encoded remain limited. Citation data are notoriously difficult to structure, because both the very notion of what constitutes a reference and the conventions governing its recording have changed over time—for instance, from references embedded in footnotes to the development of standardized bibliographies and the author–date system (Grafton 1999). Full texts face similar limitations: mathematical expressions and empirical material, such as tables, are often poorly captured or inconsistently encoded by providers. These shortcomings restrict what can be studied by quantitative tools.

A first important point is, therefore, that data availability shapes what can be asked and so answered. The scarcity and structure of available data affect every stage of inquiry, from the choice of research questions to the interpretations of quantitative results. In practice, research may be shaped as much by the scarcity of our data as by researchers' own preferences. It is of course possible to build handmade datasets from scratch, but, in the case of textual and citation data, such tasks remain time-consuming beyond small-scale study. More commonly, it is often necessary to combine information from different databases to fulfill a specific goal. For

[3]The application is available here: https://019adac8-81d4-aa0e-808c-08861c261fd2.share.connect.posit.cloud/

[4]One of the main challenges for a quantitative history of economics is to move beyond reliance on proprietary digital libraries and to actively develop open, historically inclusive corpora. This includes incorporating materials produced in non-Anglophone countries and expanding the range of textual formats considered—such as books, book reviews, working papers, and conference proceedings.

example, a medium-scale study of the publications of the European Economic Review (Goutsmedt and Truc 2023)—few thousands documents—required to combine three heterogenous databases: Econlit (for JEL codes classification) Web of Science, and Scopus (due to imperfect coverage of Web of Science).

For our study of rationality, the first step was to identify the best sources. For citation data, the Web of Science (WoS) provides the most reliable and consistent coverage for our period and has been widely used in the history of economics. As for full text, we relied on three providers. First, JSTOR's full-text collection offers high-quality scans of most leading economics journals (Jstor 2025). Second, we used Scopus to identify peer-reviewed economics journals not included in JSTOR and to compile a complementary list of articles; for these, we retrieved full texts first through the Elsevier Full-Text API, when available. Third, remaining full texts were obtained through the ISTEX project (Istex 2025), which provides access to a substantial corpus of documents for researchers affiliated with French universities.[5]

The Figure 1 shows the distribution of this corpus. It can be already noted that our corpus disproportionately represents Anglo-Saxon journals, which are also those most systematically digitized and preserved. Not only do we tend to overlook other traditions of research, but this also raises a serious issue of presentism: the fact that retrospective data on these journals are easily accessible today does not imply that they were equally central in earlier ones, nor that articles were the dominant vehicle for the diffusion of ideas. Rather, it reflects the fact that they had the resources and opportunities to digitize and maintain comprehensive digital archives of their publications.

Once access to full text is secured, another crucial step is to transform them into a usable database. While WoS citations are already delivered in a relatively structured form, full texts require substantial processing. In most cases, data are not given but result from a process that involves cleaning, categorizing, and selectively removing or reformatting information from raw sources in order to produce a dataset suitable for computational analysis. This challenge is particularly true in the history of economics, where the primary sources are the texts themselves—often unstructured and interspersed with various layers of textual content, such as section headings, footnotes, bibliographic references, or editorial annotations. This requires making important choices well before the actual stage of analysis.

Our first choice was to restrict the analysis to English-language articles, since cross-language comparisons involve additional challenges, which would go far beyond the scope of this article.[6] We also restrain our analysis to research articles and filter out book reviews, comments, editorial reports or obituaries.[7] While such materials can illuminate how rationality was debated, they are not primary sites for articulating new ideas within the discipline. Moreover, textual data are by nature voluminous, and filtering improves tractability for large-scale computation. At the document level, we focused on the body text and removed (as far as possible) peripheral elements such as acknowledgements, references, or appendices. We also focus on natural-language text and remove other information that is poorly OCR-processed and often unusable, such as mathematical formulas and data tables.

This data wrangling is not a tedious prelude to "real" historical analysis. Manipulating, cleaning, and structuring raw sources is a fundamental and often generative stage of research. As Lemercier and Zalc (2019, 62) reminds us, collecting and categorizing sources is also "a moment to reflect on the sources and the purpose of the research." Direct engagement with raw

[5]For more detailed information on the collection of data, see the appendix.

[6]Indeed, most textual methods are designed to identify commonalities within texts that share a specific linguistic structure. Hence, the same topic discussed by two documents in two different languages will likely not be identified as related because linguistic differences mask underlying semantic similarity.

[7]This filtering draws on JSTOR's and Scopus' own classifications, supplemented by some additional filtering from ourselves. Despite these safeguards, a perfectly clean restriction to research articles was not feasible, and some residual non-article items likely remain.

data can prompt the reevaluation of initial hypotheses and the emergence of new questions. In our case, preparing full-text documents raises choices about what counts as a relevant economic text. Should we include book reviews, working papers, or conference proceedings? How should we define an "economics journal"—restrict it to core outlets or extend it to interdisciplinary venues where economics appears regularly? Even within a single article, boundaries are ambiguous: should abstracts, footnotes, or appendices be analyzed or excluded? Each decision may carry historiographical implications. It shapes the corpus and, ultimately, the history of rationality our methods can reveal. There are rarely definitive and uncontestable choices, but rather a series of trade-offs that should be made explicit and required to engage with some of the material available.

To give an illustration, it is only after a first batch of exploratory analysis that we notice that some important economics journals were missing in JSTOR. If it was obvious from preliminary results that the emergence of behavioral economics impacted how economists discussed rationality, from our own expertise on the matter, we observed that some journals like the *Journal of Economic Behavior & Organization* or the *Journal of Behavioral Economics*—later to be the *Journal of Socio-Economics* and then the *Journal of Behavioral and Experimental Economics*—were missing in places where they should be predominant. This prompted us to further explore potential biases in JSTOR and to augment our corpus with new full texts extracted from Elsevier and the ISTEX project. Exploring raw sources is thus an important step that requires to already engage with your material and the existing literature.

The use of several databases also raised specific issues. Here, our goal was to combine our textual data (from the three providers mentioned above) with citation data from WoS. Achieving this required linking documents across datasets, yet WoS—like many databases—does not provide DOIs, which would otherwise serve as convenient unique identifiers. It therefore fell to us to develop matching procedures to determine whether an article retrieved from JSTOR or Scopus corresponded to the same article indexed in WoS. However, matching based solely on the title is unreliable. For example, the title *"Inflation and Unemployment"* may refer either to James Tobin's (1972) AEA presidential lecture or to Milton Friedman's (1977) Nobel lecture. Consequently, we had to supplement title information with additional metadata, including the journal name—which required standardizing journal titles across databases—as well as the publication year, volume, issue, and page range. Differences in journal coverage and in data storage practices (particularly title formatting) mean that it is generally impossible to achieve a complete match between databases. In our case, approximately one-quarter of the full-text documents after 1945 could not be matched to WoS records, which prevents us from analyzing their citation data.[8]

From data to corpus

In parallel with the transformation of sources into data, we also needed to establish the boundaries of our corpus, a process that involves selecting materials either *ex ante*, when choosing which sources to include, or *ex post*, when filtering the collected data. In the context of our project on the history of rationality in economics, this required us first to determine what qualifies as "economics," and second to identify which documents or parts of documents can be considered "texts" about rationality.

The first challenge was thus to define the extent of our corpus a priori, i.e. to delineate economics as an object of study. Some research objects are relatively easier to delineate, and the transition from a database to a well-defined corpus is therefore straightforward. For example, writing the history of a particular journal (Edwards 2020; Charles et al. 2025) or of one or several individuals (Truc 2025; Delcey 2025) entails comparatively definitional or boundary challenges. While some large-scale studies focus on the discipline as a whole (Claveau

[8] See the appendix for more information on the matching process.

and Gingras 2016; Truc et al. 2023; Ambrosino et al. 2018), such work still requires an operational definition of what are documents in "economics." This definitional issue becomes even more pronounced when the object of study is a specific "field" (Cherrier, this issue) .

Non-quantitative historical methods tend to address large objects by focusing on their "core" rather than their boundaries: historians of economics typically reconstruct the history of materials that are unambiguously part of the object under study, thus making a narrow definition often unnecessary. Quantitative approaches, however, require a well-defined corpus and consequently oblige researchers to impose simple, clear-cut boundaries on complex and ambivalent categories such as "economics". Defining the relevant historical materials therefore requires the adoption of specific conventions to approximate the object under study (Desrosières 2011). Defining a corpus constitutes a quantification convention—one that must always be assessed instrumentally, not as an absolute definition but as an operational hypothesis serving a specific research question.

Many proxies have been used in the history and philosophy of economics to define disciplines and sub-disciplines. For instance, (Goutsmedt and Truc 2023) used the JEL codes to select macroeconomic documents in a corpus of well-established economics journals, while (Truc 2022) and (Jullien and Truc 2024) relied respectively on citations data and institutional affiliations to identify the boundaries of behavioral economics. To choose a particular proxy, it is important to understand how it relates to the object under study. Both JEL codes and journal classifications—like JSTOR or Scopus classifications—can structure a corpus in ways that reflect their own histories, and researchers must therefore consider how these proxies shape the boundaries of their material. For example, while the JEL codes for neuroeconomics emerged around the same time as the first publications in the field, the JEL codes for behavioral economics appeared more than two decades after the earliest contributions (Truc 2023). A thorough knowledge of the history of the object studied is thus crucial for evaluating the adequacy and representativeness of the resulting corpus.

In our case, we first define economic documents by building the corpus from peer-review journals. This convention has both advantages and limitations. On the one hand, this approach is unambiguous, as it relies on agreeing upon a predefined list of journals, rather than, for instance, determining at the document level which individual articles qualify as economics. Moreover, journals constitute one of the main legitimate institutional markers of a discipline, alongside training programs and professional associations. On the other hand, focusing on journals means excluding other publication outlets, such as books or working papers.[9] In addition, it struggles to capture interdisciplinarity, whether in the form of interdisciplinary journals or of economists publishing in other disciplinary journals. Finally, this strategy requires the use of arbitrary criteria to decide which journals to include and which to exclude—particularly for journals at the margins of "economics", either because of their interdisciplinary orientation or because of uncertainty regarding their peer-review standards or academic practices. We eventually settled on a carefully curated list of 329 journals identified as economics journals in JSTOR and Scopus, but excluding journals that are not entirely academic, insufficiently focused on economics, or only founded within the last twenty years.[10] We were able to retrieve 289538 articles published in these journals from 1900 to 2009.

The second challenge was to restrain our corpus to documents engaging with the issue of rationality. One of the most straightforward proxies are keywords (Truc 2023). Based on a predefined list of target terms (often called a "dictionary"), this approach restricts a corpus to documents that mention these terms with at least a given frequency. In addition to its relative

[9]Adding these other outlets would pose additional challenges. For both working papers and, above all, books, no large-scale databases provide comprehensive full texts or complete reference lists. In addition, working papers raise the problem of potential double counting, as they may eventually be published in economic journals.
[10]We did not filter journals by language a priori. Indeed, many non-anglo-saxon journals also publish English articles at some more or less frequent occasions. It was thus easier to filter by language a posteriori and at the document level, once articles were collected.

simplicity, it works well for specific and unambiguous terms, like "stagflation" (Goutsmedt 2021) or "Agent-Based Models" (Baccini et al. 2025). But this approach may display several limitations when it is not the case. Indeed, it focuses on spotting occurrences of a term rather than a general idea. Just think about the various ways rationality could be discussed in the history of economics: beyond the term "rationality", economists employ various expressions that refer to close ideas such as maximising profits or expected utility, the *homo oeconomicus*, or the transitivity and completeness of preferences.

Going beyond simply searching for occurrences of "rationality" and "rational," we could have constructed an extensive dictionary of terms associated with the concept of rationality. This task requires substantial knowledge of the history of economics and of debates surrounding rationality, and thus presupposes that researchers possess adequate historical and conceptual background. Despite this, it remains difficult to prevent the dictionary-building process from introducing biases—for instance, by omitting concepts that are historically relevant but salient only during specific periods (such as "hedonism"), or by creating a disproportionate dictionary, with many terms related, for instance, to decision theory but few pertaining to macroeconomics or public economics. Consequently, this approach also constrains the potential for discovery: by setting the boundaries of the dictionary in advance, researchers may unintentionally exclude terms or themes of which they were unaware, and thus remain unaware of them throughout the analysis.

To overcome this issue, we use a Large Language Model (LLM) to identify documents—and in particular specific sentences within documents—that deal with rationality in our corpus of economic articles.[11] LLMs are trained on extremely large collections of text to learn patterns in language. In simple terms, they learn to predict missing words in a sentence or to determine whether two sentences follow each other. Through this training, the model develops billions of internal parameters that capture regularities in vocabulary, grammar, and meaning. When we input text into such a model, it translates sentences into vectors that summarize their context and meaning. This enables us to compare sentences not by the exact words they use but by their underlying ideas. For example, the same term—such as "model"—may carry different meanings depending on the surrounding context (*fashion model* vs *scientific model)* and a LLM can detect these variations. By converting words and sentences into vectors that reflect their semantic usage, LLMs make it possible to treat ideas and conceptual shifts as measurable objects, thereby opening new possibilities for the quantitative study of economic thought.

We rely on Sentence-BERT (Reimers and Gurevych 2019), an LLM designed specifically to produce sentence embeddings, that is, numerical vectors that represent the meaning of a sentence. The model assigns one vector to each sentence, which allows for straightforward semantic comparison: sentences that express similar ideas end up with vectors that are mathematically close to each other. Using Sentence-BERT, we vectorized more than 61 million sentences published between 1900 and 2009 from our database. Starting from sentences including "rationality" and "rational", we then searched for the sentences most similar to these anchor sentences. Thus, if sentence A explicitly uses the word "rationality," and its vector is close to that of sentence B—which never mentions the term—sentence B likely discusses a related idea.

Our approach does not simply consist of finding sentences that are close to the words "rationality" and "rational" over a 110-year period, though. Because our project is historical, it is crucial to consider how LLMs themselves handle historical language. LLMs are trained on billions of texts, but the overwhelming majority of these texts are recent.[12] As a result, they

[11] Our goal here is not to provide the reader with extensive details on what these models are and how we use them (see the appendix for additional details and references), but rather to provide general intuitions about the use of the LLMs, to understand the building of our corpus.

[12] Moreover, the texts used to train these models are not primarily academic articles in economics. This means that there may be important gaps between the general language patterns the model has learned and the specific vocabulary, concepts, and writing practices of our "domain" (see e.g. Zhang, Rojcek, and Leippold 2025).

tend to offer a "presentist," numerical view of language. For example, current models struggle to reproduce writing styles from earlier periods and cannot reliably infer the publication date of a text (Underwood, Nelson, and Wilkens 2025). Sentence-BERT is subject to the same limitations, and the sentence embeddings it produces inevitably reflect this bias. Besides, as illustrated by Figure 1, our corpus is exponential according to years and most sentences come from recent articles. Taken together, these effects make it very likely that the sentences the model identifies as closest to "rationality" will predominantly come from recent articles. To limit this presentist effect, we adapted the way we compare sentences over time. Instead of comparing a sentence from, say, 1910 directly to a "representative vector" of all sentences in our corpus that contain the words "rationality" or "rational," we constructed a series of representative vectors. For each year, we build a moving average vector, with a five-year symmetric window, of all the sentences mentioning "rationality" or "rational". Concretely, for the year 1910, we averaged the vectors of all sentences containing "rationality" or "rational" from 1905 to 1915. This produces a period-specific reference point that reflects how these terms were used at that particular moment in time. A sentence from 1910 is therefore judged similar not to the general, and likely modern-day meaning of rationality, but to the way the concept was expressed during its own historical period. The representative vector should be interpreted as an operational summary of the various semantic contexts in which 'rationality' is used in a given year, not as a unique theoretical definition of rationality itself. This helps ensure that our analysis is sensitive to historical changes in language. Since each document is a set of sentences, we also identify the documents—and the authors—that discuss rationality most intensively or frequently. Table 1 and Table 2 illustrate respectively the closest sentence and documents from our representative vectors in 1910.

Exploring the corpus

Simple exploration

Before returning to our specific corpus on rationality and diving into more advanced LLM-based analyses, we first step back and examine simpler quantitative methods applied to our broader set of economics articles. Indeed, quantitative approaches come in many forms and levels of complexity. In fact, quantification does not need to be sophisticated to be useful. Simple indicators may not always provide the clearest answers to research questions, but they play an important exploratory role: helping researchers refine their questions, identify anomalies, or detect unexpected patterns.

For textual data, term frequency, that is counting how often particular words or expressions appear, is a straightforward indicator. This metric has been used repeatedly in the literature, especially to track the emergence or decline of fields within economics. In well-delimited domains, term frequency can serve as a reliable proxy for intellectual dynamics. For instance, Truc (2023) shows that counting occurrences of highly specific neuroeconomics terms in economics journals—such as "striatum" or "prefrontal"—closely approximates more advanced quantitative measures, and thus provides a simple but meaningful signal of activity in the field.

Figure 2 shows the relative frequency (with respect to the total number of words published each year) of "rational" and "rationality" in our corpus. The figure reveals a steady postwar increase of the use of both terms, likely reflecting the progressive consolidation of rational choice theory in economics. We observe a marked surge after the 1970s, with a pronounced peak for "rational" in the 1980s, and a smaller peak for "rationality" in the 1990s. The rise of "rational expectations" in macroeconomics and the emergence of behavioral economics following the publication of Kahneman and Tversky (1979) likely contributed to this pattern. Of course, we cannot easily infer the precise drivers of these trends from such simple metrics. However, the clear upward movement signals an important moment in the evolution of

rationality within economics—at least in terms of textual intensity—thereby motivating more targeted forms of investigation.

While our usage of a large language model will shed light on the context surrounding this rise, such context can also be approximated with simple measures. Co-occurrence analysis helps recover the different intellectual settings in which rationality is invoked. Figure 3 reports, by decade, the five words most frequently adjacent to "rational" or "rationality," showing how these associations shift over time. Before the 1930s, the picture was heterogeneous. The notion was tied to the marginalist idea of "calculation," but it referred not only to individual behavior but also to "systems" or "organizations."simplersimpler The discussion was explicitly methodological, as indicated by the prominence of terms such as "method," "explanation," "law," and "foundation." From the 1940s onward, the rise of choice theory places rationality at the center of economic modeling as a device for describing and formalizing behavior. This is mostly visible with the rise of multiple common bi-grams (i.e., combination of two words) that remain stable from the 1930s through the 1980s such as "economic rationality", "rational choice", "rational behavior". By the 1970s—and especially the 1980s—the framework was both extended and contested. First, the most common bi-gram by far becomes "rational expectations" signalling the emergence of a new predominant concept extending rationality. In the 1980s, "rational expectations" appeared 15 more times than the other most common bi-grams. Second, while the concept "bounded rationality" was developed by Herbert Simon initially in the 1950s, the concept only became prevalent during the 1990s with the bi-gram becoming the fourth most common one.

Beyond textual data, citation data also constitute a useful source of information for corpus exploration. The evolution of an idea depends not only on how it is formulated by its authors, but also on how it is appropriated, and reinterpreted by readers. A substantial literature in citation theory examines how citations function as a scientific practice and how they should be interpreted (see, e.g., Tahamtan and Bornmann 2018). Citations may reflect a wide range of motivations—from a genuine desire to acknowledge intellectual debt to more strategic uses aimed at persuading readers or satisfying referees. Nevertheless, citations at the very least signal a relationship that can help trace the lineage and diffusion of ideas, even when the reasons behind the citation are not purely intellectual.

Counting the citations of specific documents offers a first, simple approach to assessing the impact of an author or a particular publication. There are clear reasons to incorporate citation studies into historical research. Beyond tracing diffusion, highly cited papers tend to be more visible and attract greater engagement—a dynamic that reflects the well-known Matthew effect (Merton 1968). Recent work also shows that citations influence reading behavior and perceptions of quality: highly cited papers are more likely to be read thoroughly and treated as significant intellectual contributions (Teplitskiy et al. 2022).

Historians routinely discuss scientific influence and recognition using proxies such as major grants, prizes, and honors. For example, Sent's (2004) narrative of the transition from the dominance of rational choice, through the limited success of "old" behavioral economics (with contributions by, e.g., Simon and George Katona), to the emergence of "new" behavioral economics is organized around such milestones. In this sense, citations serve as a complementary proxy alongside these traditional indicators. For instance, although both Simon and Daniel Kahneman received the Nobel Prize, Kahneman ultimately exerted a broader influence on the discipline—something that is reflected in citation patterns.

In a large qualitative–quantitative study of the Nobel Prize, Offer and Soderberg (2016) distinguished several trajectories among laureates: those who peak at the prize and subsequently decline, "innovators with staying power," "still rising" winners honored before their citation peak, and late winners recognized long after their peak. Figure 4 plots citation patterns across all WoS economics journals and across the top five journals for four seminal references that critiqued the standard approach to rationality in economics. Simon (1955) and

Allais (1953) represent early critiques of neoclassical rational choice, while Akerlof (1970) and Kahneman and Tversky (1979) are foundational contributions to what economists now refer to as "new" behavioral economics. The influence of "new" behavioral economics clearly exceeds that of the earlier tradition, both in the top five journals and in the broader set of economics journals indexed in WoS. Whereas Simon (1955) and Allais (1953) are cited by no more than 0.2% of all economics articles, Kahneman and Tversky (1979) surpasses 1% by the late 2010s and continues to rise. The contrast lies not only in the scale of influence but also in the speed and timing of acceptance: citations to the two "new" behavioral papers grow rapidly and steadily from the moment of publication, while Simon and Allais reach their modest peaks only around the time of their Nobel Prizes—or even later in the 2000s, with the renewed attention generated by "new" behavioral economics. As argued by Offer and Soderberg (2016), many laureates experience a "Nobel premium," a modest increase in citations following the award. Simon and Allais conform to this pattern, but Kahneman and Tversky represent an exceptional case: after the Nobel, their previously declining citation trajectory reverses and climbs sharply throughout the period studied (Offer and Soderberg 2016).

More advanced exploration

Citation counts are a blunt tool and cannot answer many questions of interest to historians of economics: Who cites these works? Are they cited together? In what intellectual contexts do they appear? Moreover, focusing on a small set of references introduces a degree of arbitrariness into the analysis. Likewise, simply counting the words that appear next to "rationality" tells us little about whether these words and expressions are used jointly within the same argument or whether they belong to distinct topics and contexts that mobilize the concept differently. It also overlooks the much broader vocabulary related to rationality (e.g., profit maximization, expected utility, social choice).

Most recent quantitative studies in the history of economics rely on what can be grouped under the label of "unsupervised methods." These approaches apply algorithms to a corpus—whether full texts or citation data—to generate classifications and assign categories that are not predetermined by the researcher but that emerge from statistical patterns in the data itself, which gives the approach its "unsupervised" character.[13] Assigning such categories imposes a form of internal organization on large and otherwise unwieldy bodies of material, enabling an accelerated or "distant reading" (Moretti 2013). The typical output of these methods is a map of a discipline or research area, showing how different entities—topics, articles, authors—relate to one another.

The counterpart of unsupervised methods are supervised methods—such as regressions—which estimate predefined relationships in the data. While supervised methods require clearly specified hypotheses and well-defined variables, unsupervised approaches allow researchers to let a *chosen* structure of the material emerge. This is especially true for large-scale and long-run analysis, where the risk of imposing categories that are inadequate or anachronistic relative to the historical context increases. That does not mean, however, that an unsupervised algorithm can be applied blindly to historical questions: a substantial part of our effort has consisted in adapting the method to our historical data, especially to accommodate the growth of the corpus over time.

In this paper, for citation data, we use a method commonly employed in the history of economic thought: bibliographic coupling [see e.g., Claveau and Gingras (2016); trucForty2022]. We begin with a corpus composed of the 10% of articles whose average embeddings are most

[13] "Unsupervised" does not mean that the modeller has no influence on the output. The analyst must choose a particular model and its parameters and these choices embed methodological priors about the types of patterns the procedure is likely to reveal. For instance, one crucial parameter in many unsupervised models is the number of categories that will emerge from the algorithm.

similar to our annual representative vectors for "rationality" and "rational." In this network, articles are represented as nodes, and connections between them depend on the number of shared references in their bibliographies. The more references two articles share, the stronger their link—and the closer they appear in a two-dimensional network visualization. The underlying premise is that shared references serve as a proxy for intellectual proximity. These maps help delineate the boundaries of disciplines, fields, or sub-specialties and reveal core–periphery structures.

However, citation practices tend to favor more recent works, which makes it unhelpful for historians to construct a single citation network spanning an entire century. Following a method that has proven effective in the field (Goutsmedt and Truc 2023; Camilotto 2023), we therefore split our corpus into overlapping eight-year windows, starting in 1960 (1960–1967; 1961–1968; … ; 2002–2009), and built a series of 43 separate networks. Using community-detection algorithms (Traag, Waltman, and Eck 2019), we identify groups of documents that share a substantial fraction of references and therefore have a similar intellectual background; we refer to these groups as "bibliometric communities." Our next step is to identify communities that persist over time. When two communities from consecutive networks share many of the same nodes (i.e. articles), we treat them as instances of the same underlying group—an "intertemporal bibliometric community." In this way, our bibliometric communities bring together documents from different periods of time but that are likely to engage with rationality in similar ways, based on their shared citation patterns. This method allows us both to *zoom in* on specific communities at a given period and to *zoom out* by reconstructing the broader picture of a dynamic intellectual field.

For textual data, historians of economics frequently rely on topic modeling [bakeevAcademic2023; fontanaFragmentation2023; acostaSix2024]. Topic modeling identifies the latent themes in a corpus by learning distributions of words associated with each topic. Each document is then represented by a mixture of these topics—often with one or two dominating—while each topic can be described through its most representative words and expressions. While topic modeling is a convenient tool for historical analysis, our research question pushed us toward a more targeted approach.

Because we focus on one large and historically fluid concept, we draw on the literature on semantic drift [Kutuzov et al. (2018); montanelliSurvey2024] and take inspiration from Giulianelli, Tredici, and Fernández (2020). Rather than starting with full documents, we filter each year's corpus to retain only the top 1% of sentences that are most similar to our annual representative vectors of sentences with "rationality" and "rational." In other words, we extract the sentences most likely to engage with the concept of rationality in any form.[14] As with bibliographic coupling, we want a method that groups together sentences that employ similar meanings of rationality. We therefore cluster the sentence embeddings using the HDBSCAN algorithm, a widely used unsupervised method for clustering LLM-generated vectors.

Again, historical perspective matters. Because the distribution of identified sentences is strongly present-biased (Figure 1), clustering all sentences at once would risk over-representing recent periods. We therefore perform clustering separately for each decade from 1900 onward (merging the first two decades due to fewer sentences).[15] As in our bibliographic approach, we then seek to form larger groups over time, allowing us to "zoom in" and "zoom out" depending on what we are searching for. Using the cosine similarity between clusters across decades, we merge the closest ones into 17 "intertemporal semantic clusters."[16]

[14]Taking the top 1% means that we consider, once excluded as much as we can, bibliographies, headings, etc, that 1 sentence over 100 in economics articles deal with rationality. This threshold is, of course, open to discussion and can easily be adjusted.

[15]We don't use overlapping windows in this case, notably for computational reasons: finding HDSBCAN clusters on a set of tens of thousands of sentences is much more computationally intensive than finding bibliometric communities for at most five thousands of articles.

[16]Refer to the appendix for details.

With both methods, we thus obtain a list of "intertemporal bibliometric communities" (from 1960 to 2009) and "intertemporal semantic clusters" (from 1900 to 2009). These allow us to identify subgroups within our corpus across multiple dimensions: different subfields of economics (e.g., behavioral economics, macroeconomics), different conceptions of rationality (e.g., bounded rationality, rational expectations), or even, more heuristically, different methodological traditions (e.g., experimental work, econometrics). Both approaches have clear strengths and limitations. Some are largely inherited from their respective sources. In our case, citation data cannot be meaningfully exploited before the 1960s, while our OCR full texts handle formulas and tables poorly, making economic models—an essential component of our story—less visible in the semantic analysis.

Ideally, relying on *both* methods serves complementary purposes. First, comparing the results of different unsupervised computational approaches—such as LLM-based embeddings and bibliometric analysis—acts as a form of robustness check.[17] The systematic comparison of sources and methods is a long-standing principle in historical research, allowing scholars to triangulate information rather than depend on a single perspective. Second, the two methods illuminate different aspects of intellectual history. Full texts reveal the meanings, contexts, and semantic nuances of rationality as economists used the concept in their writing, independently of their institutional proximity or citation habits. Citation data, by contrast, highlight patterns of intellectual influence and diffusion: who cites whom, how ideas travel across fields, and where intellectual boundaries lie. It conveys sometimes a more sociological dimension: scholars tend to cite the work of people publishing in similar journals, going to similar conferences, etc. The following sub-section illustrates how we interpret our results, and how the two methods complementarity may be useful.

Interpreting "Results"

Taken together, the textual and bibliometric approaches allow us to study both the semantic and thematic contexts of the uses of rationality in economics and the channels through which these ideas circulated within the discipline. But how should such a "study" proceed? Unlike simpler quantitative tools, unsupervised methods do not produce ready-made results. In our case, they generate statistical categories—bibliometric communities and semantic clusters—that lack predefined conceptual "labels." This strategy—reducing a large and complex corpus to a smaller number of coherent groups—is well established. Yet the groups themselves are created solely on the basis of statistical similarities, and their historical or conceptual significance emerges only through subsequent analysis. To make sense of what brings texts together, we therefore need indicators that identify shared features and help hierarchise the documents to be read first**.** At the same time, a good knowledge of the corpus and of the relevant intellectual debates is indispensable for making sense of the raw computational results, even once they have been informed by a set of indicators.

Therefore, whether at the stage of data construction or in the interpretation of statistical patterns, quantitative methods demand a continuous dialogue with qualitative interpretation, supported by a close reading of the secondary literature on the issues at stake. Only through this back-and-forth can we turn algorithmic groupings into meaningful historical insights. This is both a weakness and a strength. On the one hand, the analysis is not immediately transparent, as it requires the construction of intermediate tools—such as our interactive application—to guide interpretation. On the other hand, it is consistent with the practices of historians of economic thought, who likewise select, prioritise, and read texts in order to make sense of their corpus.

[17] Modeling choices (for example, the minimum size of clusters in the HDBSCAN algorithm) affect the partition in communities and clusters. Since these outputs are never self-interpreting and always require human qualitative assessment, it is time consuming to conduct robustness checks.

For the purpose of the exploration and interpretation of our results, we have built an online interactive application, where we can find all the semantic clusters and bibliometric communities, and their corresponding indicators. Let us take as an example the semantic cluster 11, which gathers close to 20,000 sentences from 1920 to 2009. How can we get a sense of what this cluster actually coalesces around? Before any qualitative interpretation or contextualization with the secondary literature, we must first produce a series of indicators to characterize the cluster. Such indicators include:

- The most identifying words of the cluster for each decade. While the first period of the cluster (the 1920s) deals notably with "rationalisation" and "human reason," the 1950s are more directly focused on "rationalism," "rationality," and "rational behavior." After the 1970s and until 2009, "bounded rationality" emerges as a core concept in this cluster.
- The most recurring authors. Talcott Parsons and Frank Knight appear frequently in the 1920s and 1930s, and Herbert Simon becomes a central author in the 1950s and 1970s. In the 1990s, we notably find Robert Sugden, a behavioral economist.
- The journals that contain the most sentences associated with this cluster. The *Journal of Economic Issues*, oriented toward evolutionary economics, figures prominently, as do more behavioral-economics journals such as the *Journal of Socio-Economics* and the *Journal of Economic Behavior and Organization*.
- The sentences within the semantic cluster that are closest to its year-representative vector, i.e., those closest to "rational" and "rationality," as well as the most representative sentences of the cluster itself for each period. The first category tends to highlight how the concept of rationality is discussed, while the second category centers more directly on the core semantic content of the cluster, often offering clues about the topics and debates that animate it in different periods. For instance, in the 1950s, one of the sentences closest to the representative vectors is Simon's claim that "If man, according to this interpretation, makes decisions and choices that have some appearance of rationality, rationality in real life must involve something simpler than maximization of utility or profit" (Simon 1959, 259–60). As for the most representative sentences, Allan Drazen (Drazen 1980, 294) warned in the 1980s that "Deciding on the suitable notion or definition of rationality is not an easy task," in his survey of the disequilibrium-theory literature in macroeconomics.
- The articles with the most sentences in the cluster for each decade. Here we find, for example, Terence Hutchison's "Expectation and Rational Conduct" (Hutchison 1937); Jacob Marschak's "Rational Behavior, Uncertain Prospects, and Measurable Utility" (Marschak 1950); Herbert Simon's 1978 Richard T. Ely Lecture at the AEA meetings (Simon 1978) and his Nobel lecture (Simon 1979); as well as Sugden's 1991 *Economic Journal* survey on rational choice (Sugden 1991).
- For the periods after the 1950s, the most cited references (based on the number of citations per article, whether the article has one or ten sentences in the cluster). In the 1950s, for example, one of the most important references within this cluster is John von Neumann and Oskar Morgenstern's *Theory of Games and Economic Behavior* (Von Neumann and Morgenstern 1944), while Kahneman and Tversky (1979) becomes the most cited reference in the 2000s.

With all these indicators—and prior to any further qualitative investigation—we can already see that this semantic cluster is centrally relevant to our study, as it bears directly on the concept of rationality itself. Our textual approach is thus able to extract some specific uses of rationality, here debates on the meaning of rationality itself in economics, allowing us to observe the evolution of these uses across time but also across topics and subdisciplines (in game theory, macroeconomics, behavioral economics, or evolutionary economics).

The bibliometric approach does not allow for such temporal or cross-subdisciplinary exploration. In our bibliometric communities, no grouping addresses rationality and its limits in general across multiple decades. Rather, bibliometric analysis identifies groups of texts from authors in close academic communities. In relation to semantic cluster 11, we observe, for instance, the emergence of a "Behavioral Economics and Choice Theory" community in the 1977-1984 window. As with the semantic clusters, for each bibliometric community in each temporal window we extract, notably, the sentences closest to the representative vectors—based on the articles belonging to the community—as well as the most cited references and the most identifying words. We also examine how each community in a given window originates (i.e., whether it derives primarily from the same or from different communities in preceding periods) and what it becomes in the following period (i.e., its subsequent "destiny").

Discussion

Equipped with these groupings and series of indicators, we can begin to make sense of our results. How can they help enrich, complete, and refine our understanding of the various and evolving meanings of rationality in economics? This paper does not propose an alternative history of the concept, which would extend far beyond the scope of this methodological discussion. Rather, we highlight selected findings that corroborate and strengthen strands of the existing literature, notably by allowing us to make claims about the prevalence and timing of considerations about rationality, while also broadening the scope of that literature and opening avenues for further research.

Throughout much of the period—but especially before the 1940s—sentences captured by our representative vectors refer sometimes less to the rationality of economic agents than to the rational character of economists' arguments, understood in terms of coherence or sound reasoning. This pattern reflects the logic of our semantic approach: LLMs tend to associate explicit mentions of rationality with broader discussions of reasoning and coherence, even when the connection to later, behavior-centered notions of rationality remains indirect. We retain this ambivalence deliberately since it reveals both historical transformation and the interpretative challenges inherent to large-scale analysis.

Our goal is also to show how we navigate the results and triangulate the indicators in order to produce coherent historical narratives. While we rely on the secondary literature, the articles we foreground are only those identified by our indicators as some of the most significant for understanding the semantic clusters or bibliometric communities.[18] We provide two complementary discussions: a macro-level perspective that highlights broad patterns in the evolution of rationality, and a micro-level analysis that focuses on the emergence of a specific topic—behavioral economics.

Through the Telescope: Broad Patterns on the History of Rationality

When our quantitative inquiry begins in 1900, the concept of rationality had already gained prominence, in line with the rise of scientific and abstract reasoning in the late nineteenth century. The scope of rational behavior was closely tied to debates on the proper domain of economic analysis (Giocoli 2003). With the marginalists, the economic agent was increasingly

[18] Of course, as in any historical inquiry of this kind, we are not entirely protected from selective emphasis, all the more so given that the scope of our study is too broad to summarize every pattern revealed by our results. Other scholars could have, at various junctures, pursued different interpretive directions on the basis of the same material. The publication of the interactive application we used to explore the results thus serves as an exercise in transparency and—in addition to being, we hope, useful for historians of economic thought more generally—allows readers to assess the robustness and limits of our narrative.

defined by calculative capacity. Jevons, for instance, portrayed the agent as a "calculating machine" balancing pleasures and pains, a view later formalized as utility maximization (Maas 1999).

In our first two decades, cluster 14 represents discussion centred on utility and brings together insights on marginal utility from, among others, Sidney. J. Chapman, Arthur Pigou, Francis Y. Edgeworth, and John M. Clark. Cluster 4 also captures discussions about utility: economic theory is debated through the history of economic thought. Arguments about utility were framed as interpretations, critiques, or extensions of classical authors—most notably Mill, Ricardo or Malthus. Yet, if anything, marginal utility theory appears mostly under severe criticism in this period, especially from institutionalist economists such as Thorstein Veblen, Wesley Mitchell, John Maurice Clark, and Rexford Tugwell.[19]

The criticism was directed along two main lines. First, as Giocoli (2003, 48–50) points out, institutionalist economists rejected the "unfounded psychological underpinnings of neoclassical economics" and sought to replace them with sounder foundations (see also Yonay 2001, 101–6). They proposed instead to renew the economic method by drawing on psychology and its emerging "behaviorist" approach (Rutherford 2001, 175–76). Semantic cluster 9—concerned throughout the period with general methodological issues in economics—captures a significant share of sentences from 1900–1920 that articulate such institutionalist critiques. For instance, Veblen (1909, 622–24) attacked the "marginal-utility school" for relying on the simplistic depiction of human behavior implied by the "hedonistic calculus." Institutionalists were energized by new developments in psychology. In his review of the literature on "Human Behavior and Economics," Mitchell emphasized the growing interest of economists in psychological matters, which stemmed from "a somewhat tardy recognition that hedonism is unsound psychology, and that the economics of both Ricardo and Jevons originally rested on hedonistic preconceptions" (Mitchell 1914, 1). For economics, the crucial issue was thus to choose "between providing a sounder psychological basis for our analysis, and holding that its psychological basis does not concern the economist" (2).[20] Such criticism did not falter in the 1920s. In cluster 11—centered at the time on "rationalisation" and "human reason"—Tugwell (1922, 317) encouraged economists to move beyond the "rigid classical *homo economicus*" and noted that "psychologists have already pretty well revolutionized the scientific definition of human nature."

Second, for institutionalist economists, institutions were indispensable for understanding economic behavior, and different institutions implied different behaviors; there was no single, context-independent *homo oeconomicus*. In cluster 9, Veblen (1909, 620) again argued against the "statical character" of marginal-utility theory, which offered "no theory of a movement of any kind," being occupied solely with "the adjustment of values to a given situation." Similarly, E. H. Downey (1910, 253), in the cluster 14, claimed that "Marginal-utility economics has nothing to say of the genesis, growth, or current working of economic institutions" (see also Rutherford 2013, 141). Its "deliverances," he argued, were therefore "futile for the problem of social betterment," since such "betterment" concerned the adjustment of institutions to changing circumstances and ideals. In the early twentieth century, economic behavior, according to institutionalists, had to be understood through the prism of the "pecuniary institutions" that shaped it. For instance, Charles Cooley (Cooley 1915) underlined that "pecuniary valuation," or economic valuation, is only possible because of the institutions that make such valuation possible (see also Rutherford 2013, 58–59). Figure 3 shows well the importance of "pecuniary" as a neighbor to "rational" and "rationality" in the first twenty

[19] However, because we focus on English, published articles, our clusters are likely biased toward American journals, notably in the first decades.

[20] Some years earlier, Mitchell (1910, 97) already pushed forward similar claims, regretting that "few economists have regarded the study of psychology as a necessary part of the equipment of their work," often relying on "tacit preconceptions" rather than to seek to "psychologists to gain a knowledge of the mind and its modes of operation."

years of the twentieth century.

The centrality of institutionalist economists—as well as the prominence of U.S. journals in our corpus—is visible in the scope of the semantic clusters in the first periods: sentences related to rationality, in addition to the clusters already mentioned, were grouped into themes related to the railway industry (semantic cluster 8), progressive taxation (cluster 17), tariffs and commercial policy in the United States (cluster 8 again and part of cluster 2), or agriculture (cluster 13). In line with institutionalism, most of these economists examined these themes through the laws and rules governing economic activity, focusing on how institutions structure the behaviour and interests of collective actors rather than on abstract individual assumptions. In these clusters, "rationality" is rarely mentioned explicitly, even if we find discussions on the behavior of "business men" (cluster 12), "workmen" (cluster 8) or "owners of land" and "farmers" (cluster 13). These clusters gradually decline in importance, and most of them disappear in the postwar period. Indeed, the period from 1930 to 1959 displays substantial transformations in the structure of debates concerning rationality.

The most obvious transformations are those described by Giocoli (2003) as "the escape from psychology" and, more generally, the shift from a "system-of-forces"—"economic processes generated by market and non-market forces"—to a "system-of-relations," in which the aim becomes to establish the existence and properties of equilibria through the "validation and mutual consistency of given formal conditions" (Giocoli 2003, 4–5). "Rationality" was progressively distinguished from "reason" or "intelligence" and recast as a formal, axiomatic notion—"rigid rules that determine unique solutions" (Erickson et al. 2013; see also Klaes and Sent 2005).

While cluster 14 (on utility) constituted only a tiny share of sentences between 1900 and 1919, and was absent in the 1920s, it gains importance in the 1930s to the 1950s (though still representing less than 5% of all sentences). During this period, the heart of the debate concerned the measurability of utility and the opposition between "cardinal" and "ordinal" utility. In the 1930s, the debate still bore on the psychological dimension of utility measurement. In 1933, John Hicks and Roy Allen (1934) coauthored an article on demand analysis that eliminated marginal utility by appealing to the concept of the marginal rate of substitution—the slope of the indifference curve (see Moscati 2019, 98–100). Already in 1932, Allen had made this project explicit: by starting from "preferential discrimination," or individuals' preferences over different bundles of goods, it becomes unnecessary to "make any assumption about the existence of 'total utility' or about the measurability of 'utility'; the hedonistic hypothesis has been rendered superfluous" (Allen 1932, 207). In other words, "Subjective and psychological concepts have been discarded from pure economic theory" (ibid.).

Yet this position was not uncontested. Indeed, in these debates, terms such as "introspection," "satisfaction(s)," and "pleasure" recur frequently in the cluster during the 1930s and 1940s (see for instance Armstrong 1939). But they disappear from the top identifying words in the 1950s. During this period, debates on ordinal versus cardinal utility continued—with a renewed defense of the cardinalist position and ongoing disputes about the very meaning of "measuring utility" (Moscati 2019, chap. 10)—yet these discussions had largely emancipated themselves from psychological or behaviorist considerations. These debates are also associated with a new cluster (cluster 5), which appears in the 1940s and grows substantially (to nearly 8% of all sentences) in the 1950s. This cluster concerns the formalization of agents' preferences and choices. Here, we encounter what would become the standard vocabulary of decision theory: "individual orderings," "preferences," "decisions," "transitive," etc., and Von Neumann and Morgenstern (1944), Friedman and Savage (1948), and Savage (1954) appear as the most cited references in the core articles of the cluster. To complete this panorama, a game-theory cluster emerges in the 1950s, which ultimately comes to represent nearly 15% of all sentences after 1990.

Transformations in the conception of rationality are also visible through clusters that remain

thematically stable over time, yet reflect profound shifts in the discipline's methodology and the growing centrality of rational choice theory. Semantic cluster 12, for instance, which spans the period from 1900 to 1979, deals with firms and entrepreneurs. In the 1920s, the cluster emphasizes entrepreneurial decision-making, understood primarily as prudence facing uncertainty rather than formal optimization. From the 1940s, this cluster increasingly centers on "profit maximization." The cluster captures the core of the so-called "marginalist controversy" (Backhouse 2009), notably through Richard Lester's attack on marginal theory and Fritz Machlup's (1946) response. Machlup mounted a defense of profit maximization and, more broadly, of marginalist theory. He rejected the evidential value of Lester's questionnaire-based surveys of entrepreneurs, while Lester replied that "at the heart of economic theory should be an adequate analysis and understanding of the psychology, policies, and practices of business management in modern industry" (Lester 1947, 146).[21] The marginalist controversy more generally provided a key intellectual background for Friedman's essay on positive economics (1953), in which he formulated the famous "as if" principle to justify, among other assumptions, profit maximization. Interestingly, in the 1950s the most cited articles within cluster 12 were Machlup's (1946) and Friedman's (Friedman and Savage 1948), both of which relied heavily on "as if" reasoning, notably to justify, in the latter, the behavior of agents regarding expected utility.

Shifts in the discipline's methodology are also captured by semantic cluster 9, which gathers sentences in which authors reflect on their own methodological choices. While in the 1920s and 1930s economists still engaged with notions such as "human nature," "passions," or "prejudices," the postwar period saw the growing prominence of terms such as "logical implications" and "assumptions," followed, from the 1970s onward, by an increasing focus on "models" and "optimality."

It thus becomes clear that by the 1950s the conception of rationality had been profoundly transformed, moving in a more formal direction and largely emancipated from psychology. Another transformation also deserves emphasis: as rationality was recast in terms of consistent choice rather than as a psychological portrait of *homo oeconomicus*, the normative dimension expanded—from individual behavior to questions of social choice and of "rationalizing" policies (Erickson et al. 2013; Hands 2015).

The emergence of this social dimension of rationality is already observable in the interwar period. In the 1930s, cluster 11 focused on the concept—relatively neglected in the history of economic thought—of "rationalization." In a literature review on this concept, Robert Brady (Brady 1932, 526) remarked that "scarcely any term… has occasioned more discussion and dispute." The concept referred to "every technique, program, or plan of organization which promised to promote (…) the 'efficiency' of individual enterprises, entire industries, or even the total of economic processes nationally or internationally considered." Attention to "rationalisation" is also visible in cluster 13, devoted to agricultural economics and the rise of "farm management" aimed at improving farmers' living conditions. It becomes even more pronounced with the multiplication of debates on economic planning and the rationalization of policy decisions from the 1940s onward, particularly in cluster 8.

As rationality increasingly came to be framed through modern microeconomics, the concept was extended to collective choice. In semantic cluster 5—gathering sentences on decision theory—the rational "decision making" is applied not only for individuals but also for firms and public policy. It is in this cluster that issues of social choice emerge, notably through debates

[21] Machlup's position was that even if a "goodly portion of all business behavior may be non-rational, thoughtless, [or] blindly repetitive" (1946, 520), questionnaire evidence and empirical findings more generally did not demonstrate the failure of marginal theory when properly interpreted. In a similar defense of profit maximization, Leonid Hurwicz (1946, 110) first acknowledged that it was not "inconceivable that business is run more by routine than by rationality," but argued that behavior may appear irrational or merely "routine" from the standpoint of a purely static theory that ignores uncertainty, while proving fully "rational" once uncertainty and long-run effects are taken into account (see also Herfeld 2018).

on the implications of Arrow's impossibility theorem (1951; see e.g. Igersheim 2019).[22] Arrow's contribution also stimulated the formation of cluster 16 in the 1960s, where it appears as the primary reference, alongside works by Downs (1957) and Buchanan and Tullock (1962). This cluster is closely associated with publications by *Public Choice* (see Cherrier and Fleury 2017). Welfare economics and public choice, as well as public finance (Desmarais-Tremblay, Johnson, and Sturn 2023), are also clearly visible in the bibliometric analysis after 1960. Indeed, one of the major bibliometric communities of the 1960s is organized around public goods and externalities, with James Buchanan, Ronald Coase, and Richard Musgrave as central references. The prominence of public finance increases further in subsequent decades, with the appearance of another community devoted to optimal taxation after 1968; taken together, these two communities account for nearly one fifth of the entire network in this period.

We have seen how the meaning of rationality progressively transformed and formalized after the 1930s, and how the rationalization of collective decision-making became central in the postwar period. So far, however, we have said little about macroeconomics. Macro-oriented issues constituted a relatively important semantic cluster from the beginning of our period, in 1900, notably through monetary economics (cluster 1). This cluster grew in importance in the 1930s, in connection with debates surrounding Keynes's work, liquidity preference, and unemployment. It is only in the 1970s, however, that this cluster becomes dominant in our panorama of rationality. This shift is closely linked to the emergence of the concept of "rational expectations," which profoundly transformed the way rationality was discussed in economics. The concept was developed by Muth (1961) but only later popularized when Carnegie colleagues—Robert E. Lucas, Edward C. Prescott, and Thomas J. Sargent—applied it to macroeconomics (Lucas 1972; Sargent and Wallace 1973). By the late 1970s, it had circulated beyond academia into policy circles and the press and was often described as a "rational expectations revolution" (Duarte 2025). Our methods help account for this rapid diffusion beyond controversial policy debates during the stagflation era. First, the results show no significant trace of rational expectations in the 1960s in either the bibliometric or textual outputs.[23] But from the 1970s onward, it occupies a central place in the literature on rationality, reaching its apogee in the 1980s, when it accounted for nearly 30% of all sentences in the textual analysis, as well as a comparable share of articles in the bibliometric analysis, spread across several bibliometric communities ("Rational Expectations and Business Cycles," "Exchange Rate Economics," and "Inflation, Expectations, and Interest Rates").

A similar trajectory to macroeconomics can also be observed in finance. The origins of financial issues can be traced to semantic cluster 3 which focused initially on the theory of investment. Until the 1930s, the issue was framed around the returns of capital. For instance, the cluster includes the so-called Hayek-Knight controversy on the conception of capital (Cohen 2003). After the 1940s, decision-making under uncertainty becomes a central theme, crystallized by works such as Shackle (1942) on investment under radical uncertainty, which figures among the most representative articles. One decade later, Jack Hirshleifer (1958) inscribed investment theory within the rising neoclassical conception of rationality, by formalizing investment decisions as a problem of intertemporal maximization of consumption. In the same vein, the Modigliani–Miller theorem (Modigliani and Miller 1958) further consolidated this shift by grounding firm financial decisions as an arbitrage problem, opening the path to modern financial economics. Their theorem, they argued, can be used "as a basis for rational investment decision-making within the firm" (Modigliani and Miller 1958, 296). After the 1960s, cluster 3 became much more prominent, consistently accounting for more than 10% of all sentences. In this period, rationality is increasingly framed in formal decision-theoretic terms and focused on appropriate investment choices under uncertainty.

[22]This grouping of sentences in the 1970s actually took its origins in the semantic cluster 14 on utility, which ended in the 1960s, with a focus on welfare economics.

[23]This highlights a key caveat of our methods. Because these methods foreground statistically "significant" patterns and indicators' prevalence, they are not always well suited to tracing and interpreting the origins of a concept or theory with the care that close historical study and archival research provide.

Hence, our analysis shows that rationality in finance enters primarily through corporate finance, rather than through asset-pricing issues such as market efficiency, where rationality long remains an implicit assumption and rarely discussed explicitly prior to the emergence of behavioral finance.

From the 1980s onward, modern asset pricing becomes dominant within cluster 3 as indicated by the growing prominence of terms such as "assets," "arbitrage," and "capital asset pricing". We also observe increasing proximities between the finance literature and the rational-expectations framework from the mid-1970s onward. This is both visible in the semantic clusters and in the bibliometric communities, in particular, the "Rational Expectations and Market Information," which emerges in the 1976-1983 window. A central contribution found in both semantic and bibliometric clusters is Grossman and Stiglitz (1980), which draws on Lucas's imperfect-information framework (Lucas 1972) and combines rational expectations with noisy signals to question market efficiency. More generally, rational expectations models—initially developed in a macroeconomic context—became a central framework for analyzing the (ir)rational use of information in finance (see Delcey and Sergi 2023).

The 1970s and 1980s thus marked a relative dominance of macroeconomics and finance, with comparatively less weight given to debates on individual rationality. This situation begins to change gradually from the 1980s onward. In the 1979-1986 bibliometric network, a "Behavioral Decision Theory" community appears (representing around 2% of the network), capturing the early emergence of behavioral economics as promoted by Kahneman and Tversky. In the 1990s, the rise of behavioral economics—together with new approaches in game theory—fundamentally altered this configuration, leading to more specialized investigations of individual rationality, which now dominate and are distributed across multiple bibliometric communities. This transformation represents not merely a shift in research topics, but a profound reframing of how economics approaches rationality: from an assumption embedded in theories and models to an object of direct investigation at the individual level.

We have sought here to offer a broad panorama of the major transformations in the concept of "rationality" in economics. This approach allows us to identify large-scale changes when they become visible in the data—namely, when particular clusters come to represent a significant share of sentences (or of the bibliometric networks). However, historians of economic thought are often concerned with understanding how such transformations came about: which contributions, authors, and communities played a decisive role. Addressing these questions requires a more focused perspective, tracing the evolution of specific topics and literatures. This is the aim of the next section, which moves beyond the panoramic view to provide a more detailed narrative of the rise of behavioral economics outlined above.

Under the Microscope: Simon's Reception and the Birth of Behavioural Economics

The term "behavioral economics" has a complex history. While it is now mostly associated with the work of Kahneman and Amos Tversky, George Katona is often credited as an early adopter of a behavioral approach (Gilad, Kaish, and Loeb 1984; Hosseini 2011). To distinguish among different strands of behavioral economics, Sent (2004) proposed an influential distinction between "old" and "new" behavioral economics. This distinction separates the heterogeneous and reformist efforts of Katona, Simon, and others to challenge mainstream economics from the more homogeneous heuristics-and-biases research program developed by Kahneman and Tversky. Sent argues that "new" behavioral economics succeeded in part because it was less radical than earlier approaches and because it emerged in the 1980s, at a moment when economic theory faced multiple epistemological challenges, thereby creating an opportune context for alternative frameworks.

The divergent fates of Simon's bounded rationality and Kahneman and Tversky's heuristics-and-biases approach thus present a striking puzzle in the history of economic thought. Both challenged standard assumptions of rationality under the banner of behavioral economics, and both were ultimately recognized with Nobel Prizes, yet their patterns of reception and adoption differed. While our methods cannot identify the precise epistemological mechanisms behind this divergence, they allow us to trace and compare the trajectories of reception and influence of these two approaches, shedding light on how and when they followed different paths.

Our analysis suggests that Simon's concept of "bounded rationality" stands as one of the most influential critiques of standard rationality in economics, particularly in its role in structuring debates about rationality itself. Simon's work dominated discussions in the 1960s and 1970s, with his seminal articles (Simon 1955, 1959) and his Nobel lecture (Simon 1979) appearing across a wide range of research areas, from social choice theory to the theory of the firm and price setting. The textual analysis highlights Simon's conceptual centrality. Semantic cluster 11, which captures discussions about individual rationality, undergoes a marked transformation following the rise of Simon's influence. In the 1950s, discourse centered on terms such as "rational," "empirical reality," and "irrationality." By the 1970s, "bounded rationality" had become the most prevalent expression in the cluster, and by the 1990s, references to "boundedly rational agents" and "procedural rationality" clearly positioned Simon's concepts at the core of economic discussions, reflecting a delayed but substantial integration into the discipline.

Moreover, Simon's impact is visible not only in the changing language of rationality but also in the growing prominence of these debates within economics. Semantic cluster 11 expands from 5.76% of all sentences in the 1950s to 7.85% in the 1980s, peaking at 9.56% in the 1990s. This growth signals a significant increase in the attention devoted to foundational questions of rationality. Citation analysis corroborates this pattern of late recognition: references to Simon (1955) rise gradually after publication, with citation peaks occurring only in the post-2000s period (see Figure 4).

However, Simon's influence remained limited in two critical respects. First, the slow diffusion of his framework meant that, by the time it achieved broad conceptual prominence, it faced direct competition from "new" behavioral economics. From the 1980s onward, semantic cluster 11 declined in relative importance, and attention shifted toward more specialized clusters addressing distinct dimensions of rationality. Clusters 5 and 15 focused on expected utility theory, risk, and ambiguity, while clusters 6 and 7 examined intertemporal and other-regarding behavior. All of these clusters expanded rapidly in the 1980s, with most of them individually surpassing cluster 11 in their share of sentences. Although these strands incorporated elements of bounded rationality, they did so primarily through the conceptual tools of "new" behavioral economics—ranging from prospect theory in the analysis of risk to experimental paradigms such as the ultimatum game in the study of other-regarding behavior (Guala 2008).

Second, Simon's conceptual influence, spearheaded by bounded rationality, never translated into stable research communities. While his framework shaped how many economists approached rationality, very few actually developed the research program he initiated. Bibliometrically, only small, unstable communities formed around Simon's work. In the 1960s and early 1970s, his ideas appeared in operations research circles (*Firm Behavior and Planning*) and organizational theory critiques of profit maximization (*Organizational Efficiency and Firm Theory*). Simon was generally associated with other researchers critical of perfect rationality: Winter (1971), which applied satisficing to firm behavior; Cyert and George (1969) on behavioral theory of the firm; and Leibenstein (1966) on "X-efficiency," challenging economics' focus on allocative efficiency. Together, Simon, Winter, Cyert, and Leibenstein formed a diverse organizational theory critique of how rationality, especially through profit maximization, is employed in economics. While this collective movement had some momentum, none of these research had an individual effect on economics structure (see also Sent 2004).

After 1969-1976, this research stream coalesced into a smaller, short-lived community before fragmenting. References to Simon and critiques of profit maximization remained scattered, moving through several small communities (e.g., *cl_761*, *cl_251*, *Welfare Economics and Public Finance*, *Evolutionary Economic Theory*) without ever achieving the critical mass. While Simon's influence in economics was conceptually enduring, it remained marginal as a structuring force, unable to generate coherent, large and stable research communities.

"New" behavioral economics reception reveals a dramatic contrast. Unlike Simon's trajectory, the heuristics and biases research program of Kahneman, Tversky, and other "new" behavioral economists generated multiple stable clusters that formed well-identified and substantial research communities. A main "Behavioral Decision Theory" cluster emerged in 1979-1987, structured by early adopters of the new approach. The crystallization of this distinct cluster signaled the beginning of explosive growth and the spinning off of several autonomous communities that captured emerging specialized areas of behavioral economics: pro-social behavior and behavioral game theory (*Behavioral Game Theory*), intertemporal decision-making and risk (*Behavioral Economics and Choice*), and behavioral finance (*Financial Market Expectations*).

By the 2000s, behavioral economics had become the dominant venue for research on rationality. Three behavioral economics communities represented approximately 30% of the entire network with many additional communities structured by behavioral economics research without being explicitly characterized as such. The scale and speed of acceptance differed dramatically from Simon's experience. By 1980, Kahneman and Tversky (1979) had already surpassed Simon (1955) in annual citations (Figure 4). By 1985, prospect theory had already surpassed the lifetime citation peak that Simon's work would ever reach within economics. By the 2000s, most microeconomic publications addressing rationality were explicitly connected to the behavioral economics research program. While bounded and procedural rationality remained frequently invoked concepts, no subsequent research community clearly carried Simon's legacy as a stable bibliometric anchor.

The contrast is stark and raises fundamental questions about disciplinary reception. Our quantitative study yields two particularly surprising results regarding the contrasting influence of Kahneman and Simon. First, the temporal patterns of adoption differ radically. For the historian Heukelom (2014), a pivotal moment in the history of behavioral economics was the explicit creation of research programs within the Sloan and Russell Sage Foundations between 1984 and 1992, notably fostering the Kahneman–Thaler collaboration that decisively transformed the field's trajectory. Our analysis, however, suggests that a distinctive dynamic was already underway by the early 1980s in the reception of Kahneman and Tversky's work. Despite the fact that Kahneman and Tversky (1979) was the duo's only publication in an economics journal until 1985—well before the Sloan–Russell Sage programs formally institutionalized behavioral economics—prospect theory experienced rapid and sustained citation growth (Figure 4). As early as the 1977–1984 bibliometric network, we identify a cluster structured around their work, indicating that the article not only attracted citations but quickly catalyzed new research strands, in a way Simon's work never did within economics (Heukelom 2012).

The second surprising finding concerns the relationship between "old" and "new" behavioral economics. Contrary to narratives of rupture or forgetting, citations to Simon (1955) have never been as high as during the rise of new behavioral economics—a paradoxical pattern given recurrent claims that the field has neglected its intellectual roots. Earl (2022) criticizes this apparent amnesia:

> "Neither Kahneman nor Thaler have sought to promote earlier behavioral economics alongside more recent work. Instead, they give the impression that behavioral economics started around 1979–1980 with the publication of Kahneman and Tversky's (1979) article on prospect theory and that theory's use by Thaler (1980). All in all, this is a very curious

> state of affairs: a cynic might suggest that it looks rather as if the earlier work has been airbrushed from the history of economic thought by the strategic redefinition of what constitutes behavioral economics. A more charitable and reflexive view would see the situation as resulting from insufficient familiarity with the earlier literature" (Earl 2022, 2)

The rising citations to earlier work by Simon and Allais demonstrate that, while "new" behavioral economists may not consistently acknowledge the contributions of "old" behavioral economics, the rapid expansion and growing scale of the field have nevertheless drawn unprecedented attention to these earlier works, far exceeding the recognition they received at the time of their original publication. This pattern admits at least three interpretations, each carrying distinct implications for how we understand the evolution of economic thought.

A favorable interpretation holds that "new" behavioral economics has genuinely revived previously abandoned research directions, moving toward a reconciliation with earlier strands—a trajectory explicitly advocated by Sent (2008) and more recently by Earl (2022). A more critical reading emphasizes intellectual appropriation, whereby classic references are selectively reframed to fit the new agenda, renewing interest but through a biased and presentist lens, as Mongin has argued in the case of Allais (Mongin 2019). A third interpretation suggests that rising citation counts reflect a growing backlash against the "new" behavioral program, as defenders of "old" behavioral economics increasingly invoke Simon and others to challenge the heuristics-and-biases framework.

Our findings tentatively support the second interpretation. The sparse and weakly structured citation patterns associated with "old" behavioral economics, combined with the fact that contemporary discussions of rationality are increasingly framed through the concepts and tools of "new" behavioral and experimental economics, point toward appropriation rather than genuine integration. Citations may acknowledge earlier work without engaging its distinctive methodological commitments or theoretical ambitions. Simon's influence thus persists primarily as a symbolic and framing reference, useful for situating debates and reconstructing intellectual lineages, while his substantive framework remains only superficially incorporated. Although a definitive assessment would require closer qualitative analysis of how these citations function in contemporary texts, our study provides a quantitative roadmap for future research on the complex and ambivalent relationship between "old" and "new" behavioral economics.

Conclusion

This article is first and foremost methodological: it aims to demonstrate, through a concrete application, the usefulness of quantitative methods for the history of economic thought. Nonetheless, it does so by breaking new ground in the history and philosophy of economics. First, the corpus we build—comprising nearly 290,000 full-text economics articles spanning more than a century—is, to our knowledge, the largest and most comprehensive database ever used to study economic contributions in English. Second, this article constitutes the first application of quantitative methods to the study of semantic change within the history of economics, an area that represents an important and growing strand of the broader literature on quantitative text analysis (Montanelli and Periti 2024).

Our approach allows us to identify, within this corpus, the sentences most closely associated with the words "rational" and "rationality" and, by extension, the articles most likely to engage with rationality in one way or another. By allowing the algorithms to identify dozens of semantic clusters and bibliometric communities within short temporal windows (eight years or a decade), and by then aggregating these groupings over time and characterizing them through multiple indicators, we can conduct analyses at different scales. This makes it possible both to *zoom out*, by examining the overall configuration of clusters across periods, and to *zoom in*, by

focusing on subsets of clusters more directly concerned with rationality. As shown in the previous section, a panoramic view that considers all semantic clusters may initially include groups that appear only loosely connected to rationality—especially in the early decades. While examining these clusters can be informative for understanding the broader intellectual context, the analyst can also foreground more explicitly rationality-oriented clusters when addressing more targeted research questions. This flexibility is only possible because the initial corpus is sufficiently inclusive, reducing the risk of overlooking relevant developments. More generally, our approach allows the scale of analysis to be adjusted to the question at hand, rather than imposing it ex ante.

We want to conclude by drawing several general methodological and historiographic claims from the approaches developed in this article.

First, although quantitative methods in the history and philosophy of economics have been applied mainly to the postwar—and often post-1970s—period, our study shows that they can also be used effectively for earlier periods. Despite problems of text recognition in JSTOR articles prior to the 1930s, our methods nonetheless provide a fine-grained depiction of economic debates in the early twentieth century. In particular, we were able to recover most of the institutionalist contributions on rationality highlighted by Rutherford (2013) and Yonay (2001). At the same time, our results bring to light additional contributions not covered in these accounts, thereby opening avenues for further inquiry. Of course, some important works remain absent because they were published as books rather than journal articles. This limitation suggests that extending the corpus to include books would be a worthwhile direction for future research.

Second, a key property of groupings produced by unsupervised methods is that they bring together documents that share cognitive content without presupposing agreement. The texts clustered together address the same objects or problems, but they may do so in divergent, and sometimes opposing, ways. As a result, our methods make it possible to identify sites of resistance to dominant models or ideas. What emerges most clearly are the objects that attract sustained attention; within those sites, one can then examine who endorses, revises, or contests particular ways of treating them. This feature opens the way to a more "symmetrical" historical analysis (Bloor 1976), one that gives analytical weight not only to intellectual "winners" but also to those whose positions did not ultimately prevail.

Finally, these methods are also "discovery tools." While they can be used to confirm or challenge existing claims in the history and philosophy of economics, they also help identify patterns that have so far been absent—or only marginally present—in the historical literature. We have briefly pointed to some of these patterns above. By making available an interactive application to explore our results, we hope to encourage readers to pursue their own paths of discovery within the corpus.

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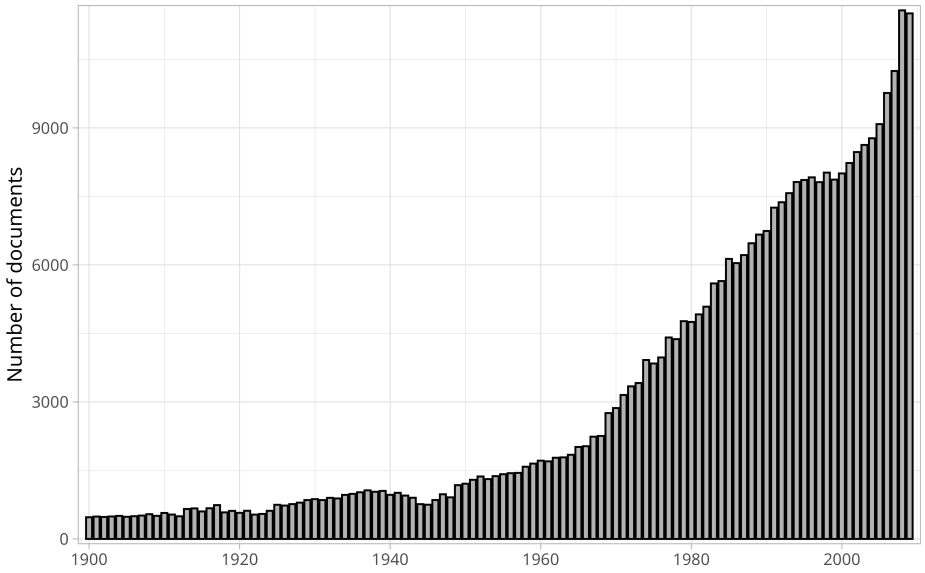
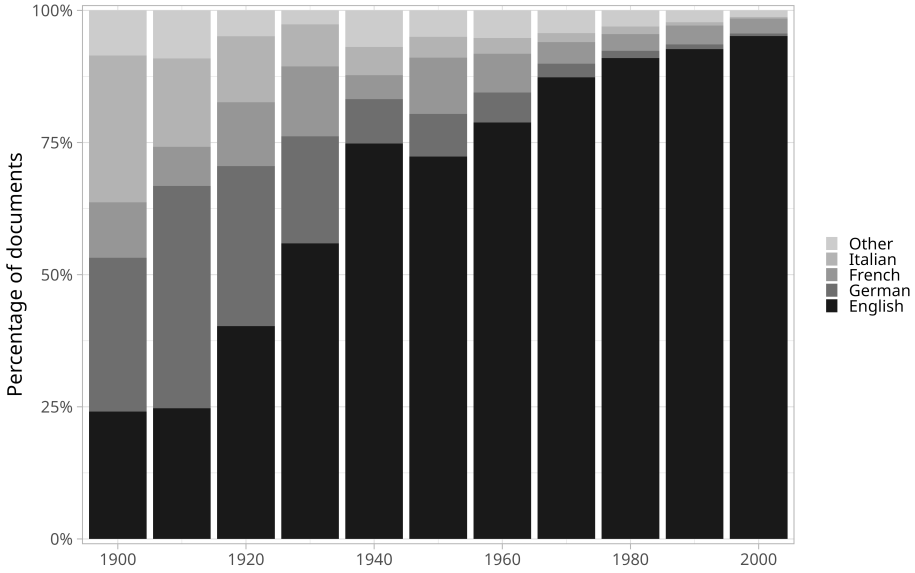
Figures



(a) Documents



(b) Languages

Figure 1.: Distribution of documents and languages in the full-text database over time (1900-2009).

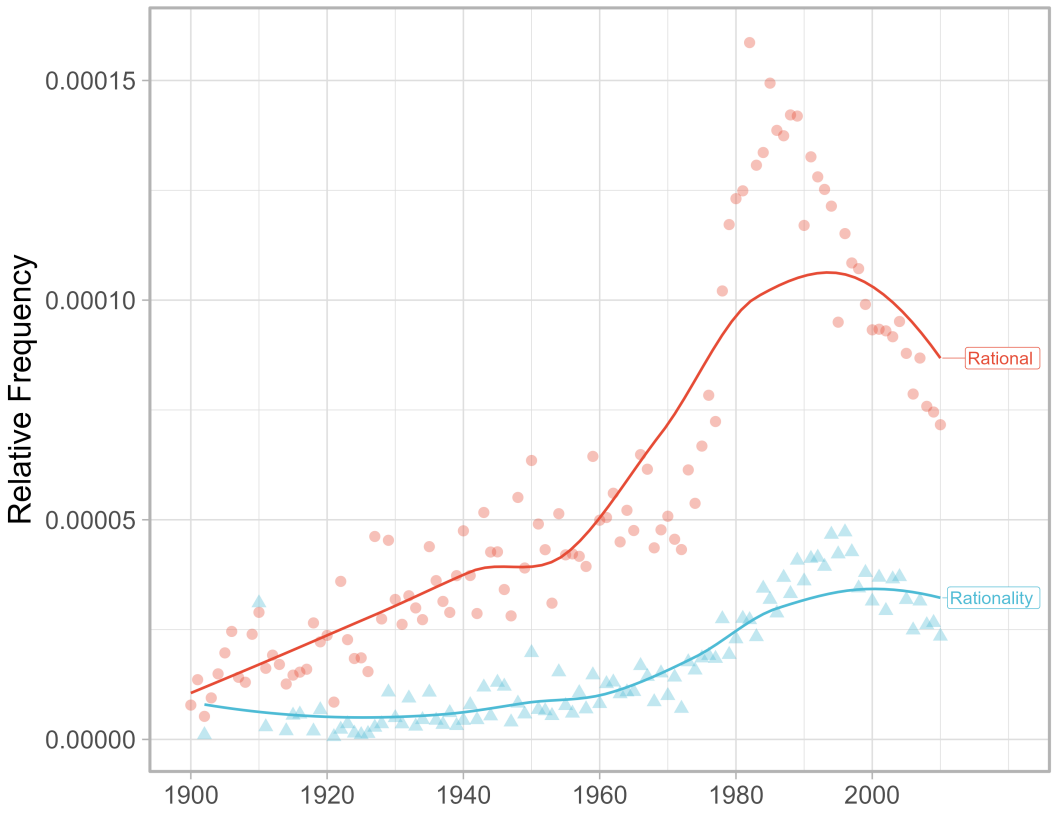


Figure 2.: Relative frequency of terms "rational" and "rationality" in the jstor database (1900-2009). Points are the empirical data. Lines are the loess smoothed trends.

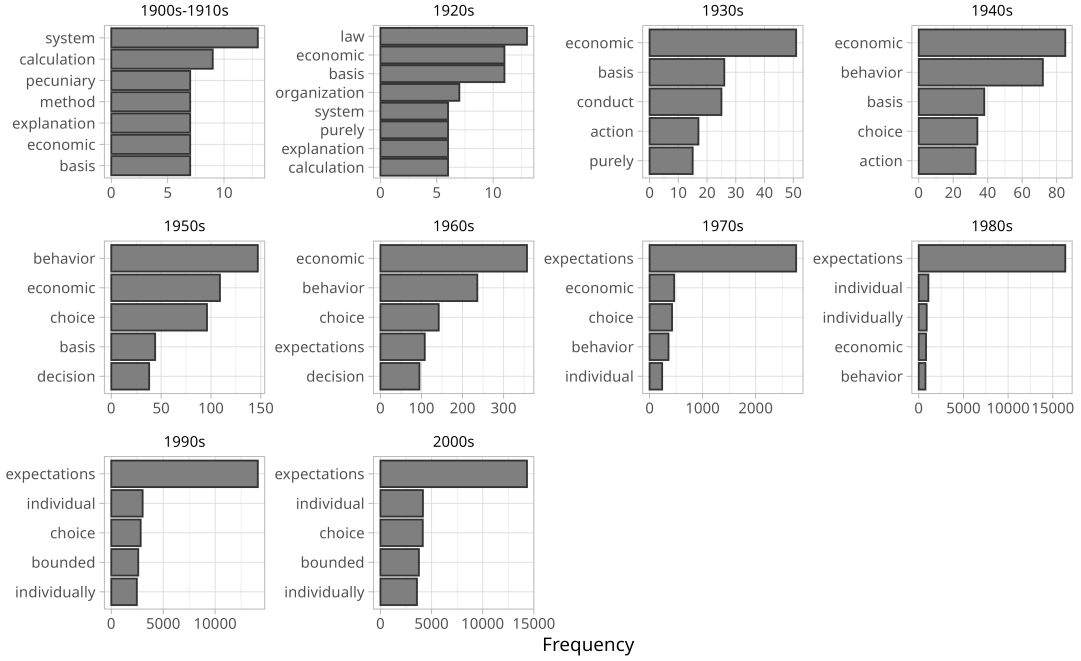


Figure 3.: Most frequent neighbor terms of "rational" and "rationality" by decade

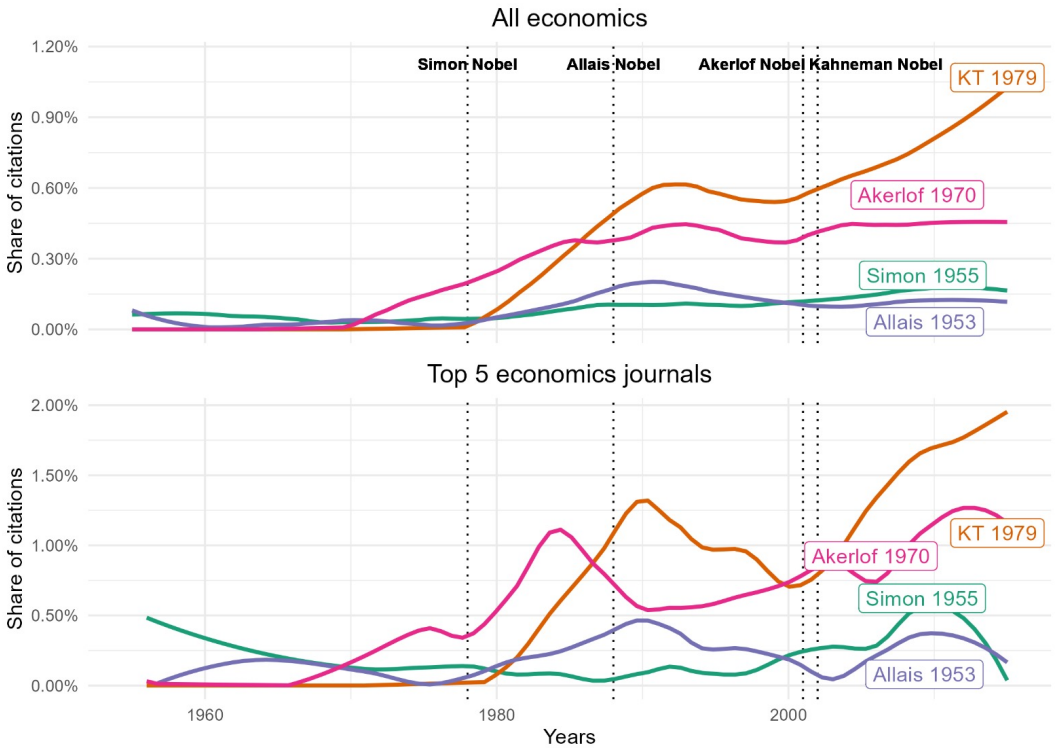


Figure 4.: Relative citation of a selection of seminal papers on behavioral economics

Table 1.: Sentences from the corpus closest to the representative vector in 1910.

Sentence	Cosine similarity
From another side, the concepts supply the basis for rationality.	0.690
The recital is important only as tending to show that a theory of valuation which places the emphasis upon rationalistic appraisal overlooks the most important features of the process which it seeks to explain.	0.686
Complete reliance may be placed upon the rationality of both the pecuniary and the hedonic subject.	0.678
It is exceedingly doubtful whether such hyper-rational view of human nature could have gained wide credence among men not themselves disciplined in the use of pecuniary concepts.	0.670
More fundamental is the great problem of accounting for economic rationality itself.	0.656

Table 2.: Documents from the corpus closest to the representative vector in 1910.

Title	Authors	Journal	Cosine similarity
The Rationality of Economic Activity	Wesley C. Mitchell	Journal of Political Economy	0.862
Social Productivity Versus Private Acquisition	H. J. Davenport	The Quarterly Journal of Economics	0.824
The Futility of Marginal Utility	E. H. Downey	Journal of Political Economy	0.786
Observation in Economics. Annual Address of the President	Davis R. Dewey	American Economic Association Quarterly	0.778
The Economics of Henry George's "Progress and Poverty"	Edgar H. Johnson	Journal of Political Economy	0.765

Note:
Documents vectors are vector centroids of all sentences in the document.

Appendix

We provide here an overview of the data and methods used to build our databases and our methods to build intertemporal semantic clusters and bibliometric communities. Figure 5 summarizes the general workflow. We describe the construction of the full-text database, the computation of sentence embeddings and representative vectors of rationality, and the clustering methods used to build our semantic clusters and bibliometric communities.

Collecting data

The full-text database is built from three main sources: JSTOR, Elsevier and ISTEX. The main source is JSTOR, which provides the largest coverage of historical economics journals. However, some important economics journals published by Elsevier are missing from JSTOR. We therefore complement JSTOR with documents from SCOPUS journals using two supplementary sources: Elsevier and ISTEX. We used Elsevier API to access Elsevier's economics journals full-texts after 1997; we used ISTEX to retrieve older Elsevier documents.

To identify economics documents, we first created a list of economic journals to query these databases. We built a list of journals classified as economics in our sources and in Econlit and then review them manually to ensure they are economics and academic journals. We also filtered out very recent journals (less than 20 years old). The rationale is to focus on journals with a sufficiently long publication history to allow meaningful intertemporal comparisons. This criterion primarily aims to reduce short time-series effects. We end up with 316 unique journals. The list of journals is available in the supplementary material. Once we have the list of journals, we queried each source to retrieve all available documents published by these journals between 1900 and 2009. We keep only documents classified as research articles (i.e., we remove editorials, book reviews, etc.) and written in English.

This results in a total of 289538 documents that represent our curated metadata. Table 3 summarizes the sources of our full-text database. Each source provides documents at different levels of granularity: Elsevier provides paragraph-level data, JSTOR page-level data, while ISTEX provides no such segmentation. Quality also varies across sources. While JSTOR and ISTEX provide raw OCR full-texts, Elsevier provides structured full-texts divided into paragraphs, which we parse to extract paragraphs. It is a higher quality of text segmentation

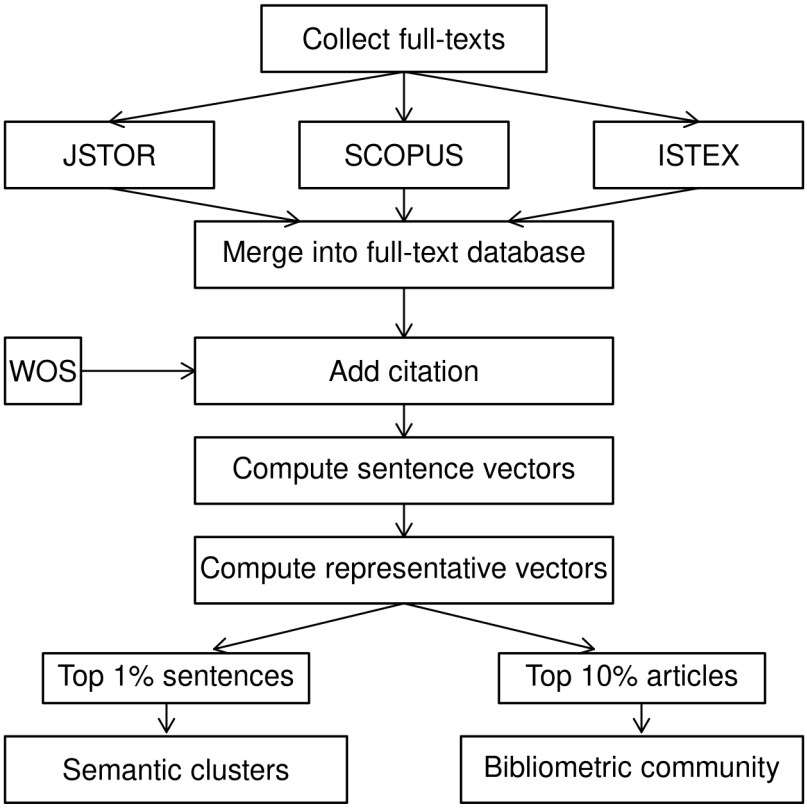


Figure 5.: Workflow of the method.

Table 3.: Sources of the full-text database.

Source	Documents	Journals	Unit of text	Format	WOS matched
ISTEX	84792	136	full text	raw OCR	33.6
JSTOR	166185	173	page	raw OCR	67.2
NA	38561	58	full text	raw OCR	79.4

compared to raw OCR that do not distinguish main text from other elements (headings, footnotes, *etc.*).

We enrich our full-text database with citation data from Web of Science (WOS). The main challenge is to match documents from our full-text database with WOS records. To match the fulltexts to WOS citation data, we apply a series of deterministic matching strategies, starting with strict combinations of metadata (title, journal, volume, issue, year, and page ranges, etc.). Table 3 indicates the proportion of documents successfully matched to WOS records for each source. After 1950—citation data are rare before this date—we achieve an overall match rate of 62%.

Sentence embeddings

We compute sentence embeddings with Sentence-BERT, using the pretrained model `sentence-transformers/all-mpnet-base-v2`. This model yields a single 768-dimensional dense vector per sentence. It has been shown to perform well on various semantic textual similarity tasks and is widely used in natural language processing applications. We use the `sentence-transformers` Python library to compute the embeddings.

In order to split textual units into sentences, we first use the `sent_tokenize` from the NLTK Python library. This function applied basic rules to split text into sentences based on punctuation and capitalization. While there are more advanced models for sentence segmentation (e.g., `spacy`), they are computationally intensive and not easily scalable to a corpus of millions of sentences. This rule-based segmentation may amplify noise in OCR-based texts such as those from JSTOR and ISTEX, which often contain punctuation and capitalization errors. One important issue with OCR texts is page break. When a sentence is split across two pages, the tokenizer may fail to recognize it as a single sentence. For instance, page breaks or footnotes may lead to the erroneous merging of unrelated textual fragments. Such errors cannot be fully corrected at scale; however, given the size of the corpus, their impact is expected to average out in aggregate analysis. We only remove sentences for which the segmentation is almost certainly incorrect and provide no information, i.e., sentences that contain less than 20 characters, less than three words, or contain more than 50% digits.

A more serious issue is the presence of paratextual sentences (e.g., affiliations, acknowledgements, headers, references) in JSTOR and ISTEX OCR full-texts. These sentences introduce important noise. For instance, because references often contain similar wording (e.g., "Journal of…", "Vol.", "pp.", etc.), they tend to cluster together in the embedding space. We use this property at our advantage. Because paratextual sentences tend to be semantically similar, they form dense regions in the embedding space, which we exploit to identify and remove them. We first define four categories of noisy sentences: affiliations, acknowledgements, headers, references. For each category, we use regular expressions to identify a set of sentences that likely belong to this category. We compute (i) the centroid vector of these sentences and (ii) the cosine similarity between those centroids and each sentence embedding. Sentences that are above a certain similarity threshold are flagged as noisy and removed from the document. We determine the similarity threshold using Youden's J statistic, computed by contrasting

regex-identified noisy sentences with a random sample of other sentences. Because the filtering operates at the sentence level and targets dense regions associated with paratextual material, occasional false positives are unlikely to affect aggregate semantic trends.

Representative vectors

For each year, we keep sentences whose text matches "rational" or "rationality", (regex: `\brational(?:ity)?\b`) excluding any sentences flagged as noise and any records outside the curated metadata. We compute the mean of these sentence embeddings to obtain a year-specific representative vector of rationality. We compute an unweighted centered moving average over an 11-year window (year $t \pm 5$) to produce the final representative vector series used in subsequent similarity calculations. We rely on an unweighted procedure—averaging each year's vectors before averaging across the 11-year window—in order to smooth short-term fluctuations while avoiding an overemphasis on more recent conceptions of rationality.

Semantic clusters

This section details the text clustering methods used to identify semantic clusters related to rationality over time. Figure 6 shows the workflow. We describe each step in detail.

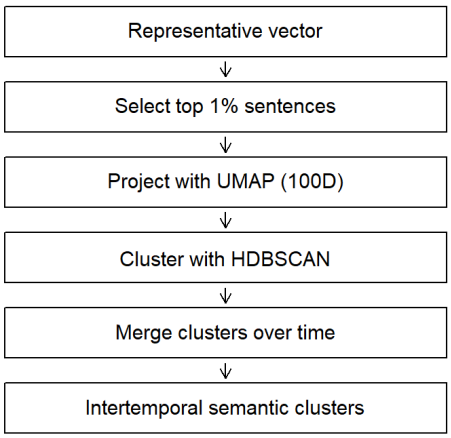


Figure 6.: Text clustering workflow.

Selecting sentences related to rationality

To identify the sentences most closely related to rationality, we compare every sentence embedding to the year-specific representative vector (RV). For each year, we compute cosine similarity between each sentence vector and the RV of the same year. We retain the top 1% most similar sentences. This threshold balances two competing objectives. On the one hand, we want to capture a sufficient number of sentences to represent the diversity of ways rationality is discussed in each year. On the other hand, we want to focus on sentences that are strongly related to rationality to avoid diluting the analysis with less relevant content.

Clustering with HDBSCAN

We cluster the top 1% sentences within temporal windows using HDBSCAN. To make clustering tractable while preserving semantic structure, we first project the 768-dimensional sentence embeddings to a 100-dimensional UMAP space (metric = cosine, n_neighbors = 15, min_dist = 0.0). Intuitively, the rationale for using UMAP is that high-dimensional spaces are often sparse, making distance-based clustering less effective. UMAP finds a lower-dimensional representation of the data that preserves information of the original high-dimensional space. This is a standard practice in text clustering workflows (e.g., Benz et al. 2025).

The UMAP fit uses a sampling strategy that keeps all pre-1980 sentences and caps the post-1980 years at 30,000 sentences each, then we transform the full dataset with the fitted model. This approach aims to avoid over-representing recent years in the UMAP fit while retaining their semantic structure. We define time windows as 1900–1919 (merged) followed by standard decades from 1920–1929 through 2000–2009. Within each window, we run HDBSCAN on the UMAP coordinates. HDBSCAN's hyperparameters, in particular `min_cluster_size` and `min_samples`, influence the granularity of the clusters and have to be chosen given the data and research question. We set `min_cluster_size = max(20, 1% of total sentences in the window)` and `min_samples = 1`. These parameters were selected based on empirical inspection of cluster interpretability. Figure 7 shows the distribution of noisy vs clustered sentences and the number of clusters identified per time window by HDBSCAN.

Merging clusters over time

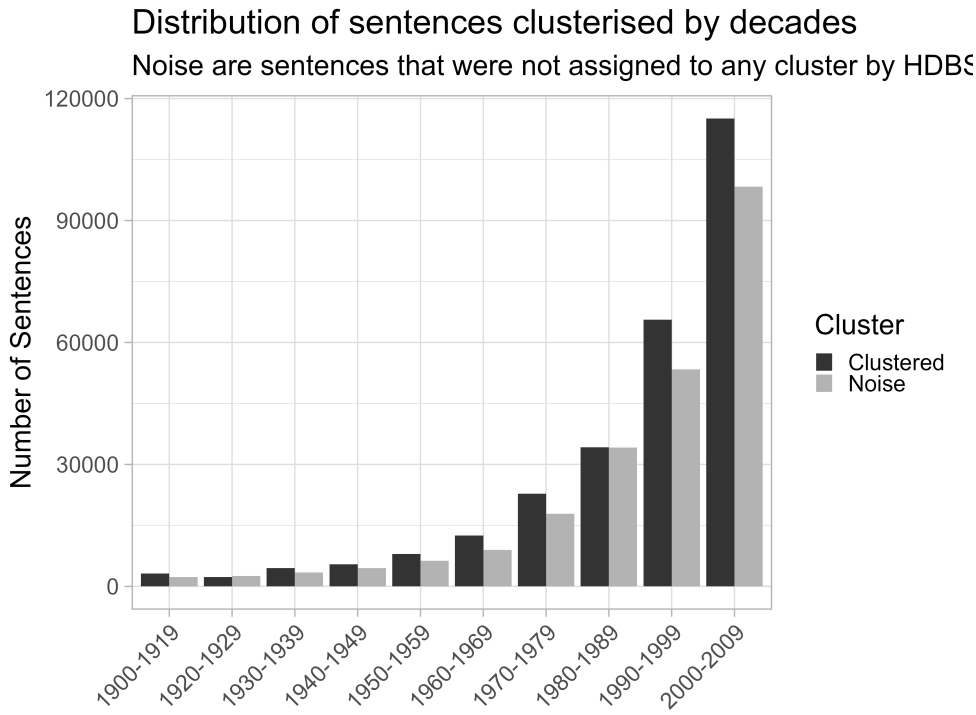
We link the clusters across time windows to recover intertemporal semantic clusters. Several strategies could be used to link clusters across time windows. We could, for instance, merge clusters that are very close in the embedding space. However, the choice of distance threshold is arbitrary and clusters may be close to multiple other clusters, making one-to-one merging too restrictive. We instead chose a network-based approach. We compute a centroid for each HDBSCAN cluster (the mean of sentence embeddings). Next, we compute cosine similarity between all cluster centroids. This gives us a weighted network where nodes are decade specific clusters and edges are cosine similarities between their centroids. We keep only the most significant links using a backbone extraction (Domagalski, Neal, and Sagan 2021), using the LANS (Local Adaptive Network Sparsification, `alpha = 0.02`). LANS retains edges that represent statistically significant similarities relative to a null model in which the weights are randomly distributed among the node's edges. We apply the Leiden community detection (resolution = 2) on the backbone network. Intuitively, clusters that are strongly connected in the backbone network are grouped into intertemporal meta-clusters.

Bibliometric data and methods

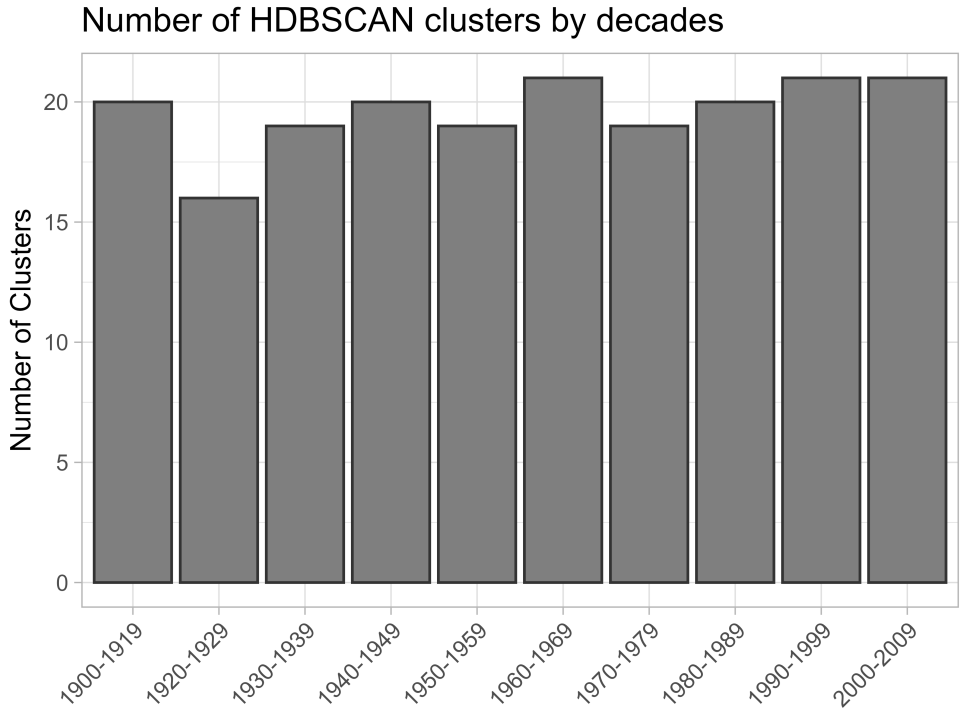
This section details the bibliographic coupling and community detection workflow. Figure 8 summarizes the steps schematically. We describe each step in detail.

Dynamic coupling networks

Networks were constructed using bibliographic coupling, where two publications are linked if they cite common references. This approach identifies articles that draw on similar intellectual foundations, revealing thematic communities within the literature. Raw common references counting can be misleading, as articles that cite many references overall are more likely to share citations by chance and references that are highly cited are also overall more likely to link to articles by chance. To weight shared references between two articles, we use the coupling strength method from (Shen et al. 2019). Coupling strength weighs both the size of the reference list of articles and the number of overall citations of each reference to overweight



(a) Noisy and clustered sentences



(b) Number of clusters by period

Figure 7.: Distribution of noisy vs clustered sentences and number of clusters per time window.

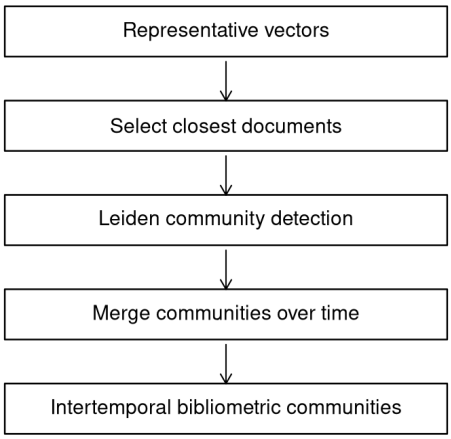


Figure 8.: Bibliographic coupling and community detection workflow.

significant co-occurrences of references.[24]

To study the evolution of networks over time, we employed a dynamic windowing approach:

- Time window: 8 years
- Overlapping windows: windows overlap to allow smooth temporal transitions (1980-1987, 1981-1988, etc.)
- Edge threshold: articles are only connected if they have at least 2 shared references

For each time window, we removed isolated articles (articles with no connections) and small components (connected groups of articles disconnected from the main network) ensuring that the analysis focused on the coherent and relevant literature.

Clustering algorithm, spatilization, and intertemporal analysis

Communities within each network were identified using the Leiden algorithm with modularity optimization (Traag, Waltman, and Eck 2019). This algorithm identify groups of articles that are have strong connections to each others, but few connections to the rest of the networks (i.e., relevant sub-groups of articles across the main network).

To identify the most relevant clusters across multiple networks, we made to an intertemporal analysis of our cluster. To trace the evolution of research communities over time, we linked clusters across consecutive time windows. Communities were considered continuous if they shared at least 50.1% of their members across two time windows. For example, if a cluster in the 1990-1997 network is made of similar articles as another cluster in the 1991-1998 network, the cluster are identified as the same one. This approach allows us to follow how research communities emerge, grow, split, merge, or decline over the 50-year period.

[24]Statistical determination of edges are best options but are computionally unfeasable given the size of our networks

For visualization and interpretation, see the application.[25] We focused on substantive communities using two criteria:

- Temporal persistence: Communities must appear in at least 2 time windows
- Size significance: Communities must represent at least 5% of the network in their peak window

Smaller or more transient clusters are uncolored in visualizations to emphasize the major research streams.

To visualize individual networks, articles (nodes) are color-coded by intertemporal clusters and spatiliazed in a two-dimensional space using the Force Atlas 2 algorithm (Jacomy et al. 2014). This layout enhances readability by positioning similar articles in close proximity. However, these visualizations are intended as heuristic aids rather than primary analytical tools. The study's findings are grounded in quantitative network metrics and detailed tables rather than visual analysis.

Characterizing Research Communities

As a way to have a first exploratory labels for clusters, names were generated using a local open large language model (Gemma 3 27B) through the Ollama framework. For each community, we provided the model with:

- The 20 most frequently cited references (with titles when available)
- The 20 most productive authors
- The 20 highest TF-IDF terms

The model was prompted to generate concise labels capturing the thematic focus of each cluster. Note that these labels are not definitive but serve as starting points for interpretation.

[25] https://019adac8-81d4-aa0e-808c-08861c261fd2.share.connect.posit.cloud/