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Characterizing a legal–intellectual culture: Bacon, Coke, and seventeenth-century England

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Abstract

A characterization of the ideas of Francis Bacon and Edward Coke, two preeminent English lawyer-scholars, provides insights into the nature of the legal–intellectual culture of early seventeenth-century England. This emerging culture remains underexplored, even though it immediately preceded and provided essential input into the 'culture of growth,' the eighteenth-century cultural paradigm viewed as a catalyst for England's historically unprecedented technological advance and economic growth. To develop insights, we employ a methodology not previously used in this context, applying structural topic modeling to a large corpus comprising the works of both Bacon and Coke. Estimated topics span legal, political, scientific, and methodological themes. Legal topics evidence an advanced structure of common-law thought, straddling ostensibly disparate areas of the law. Interconnections between topics reveal a distinctive approach to the pursuit of knowledge, embodying Bacon's epistemology and Coke's legal methodology. A key similarity between Bacon and Coke overshadows their differences: both sought to build reliable knowledge based on generalizing from particulars. The resulting methodological paradigm can be understood as reflecting a legacy of common-law thought and constituting a key contribution to the era's emerging legal–intellectual culture. More generally, our analysis illustrates how machine learning applied to primary texts can aid in exploration of culture.

Keywords Culture · Bacon · Coke · England · Seventeenth century · Machine learning

JEL Classification B31 · Z10 · N73 · K10 · P10

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1 Introduction

For those interested in the cultural determinants of development, the story of England's early rise raises the question of what were the principal features of English culture during the critical seventeenth century. Certainly some have argued that it is features of early seventeenth-century English culture that made England increasingly distinctive. This perspective is vividly captured in Wootton's (2015) characterization of the seventeenth-century scientific revolution: '…let us take for a moment a typical well-educated European in 1600—we will take someone from England, but it would make no significant difference if it were someone from any other European country as, in 1600, they all share the same intellectual culture… Within a few years change was in the air…But now let us jump far ahead. Let us take an educated Englishman a century and a quarter later, in 1733, the year of the publication of Voltaire's Letters Concerning the English Nation [whose message] was that England had a distinctive scientific culture: what was true of an educated Englishman in 1733 would not be true of a Frenchman, an Italian, a German or even a Dutchman.' Indeed the message of Voltaire's book was of a distinctive culture in general, in all of its social, political, and economic manifestations. For example, the legal and political sphere had been increasingly permeated by common-law thinking, an idiosyncratic product of many centuries of legal evolution (Baker 2019). Thus, '[b]y the seventeenth century, England had developed a political culture completely comfortable with sophisticated legal concepts…[A] legal disposition of mind…was being increasingly brought to bear upon political and constitutional problems. It conditioned men's thought and language and ultimately their actions' (Nenner 1977: x).

What were the principal features and constitutive elements of the legal–intellectual culture that emerged in early seventeenth-century England? We address this question by undertaking a quantitative, machine learning analysis of the writings of two authors, Francis Bacon (1561–1626) and Edward Coke (1552–1634). We take this approach for five reasons. First, the fundamental contributions of Bacon and Coke came at a time when the underpinnings of the later seventeenth-century legal–intellectual culture were emerging, as made clear by Nenner (1977), Wootton (2015) and others (Cromartie 2006; Hill 1997). Second, as the foremost lawyer-scholars of their age, Bacon and Coke were immensely important in the development of those underpinnings. Third, the existing literature largely characterizes the ideas of Bacon and Coke as conflicting, or at the very least orthogonal. If our analysis finds commonalities between these supposed opposites, then the common features of their thought can be viewed as reflecting important aspects of the broader legal–intellectual culture.

Fourth, the most reliable way to estimate the features of a past culture is by going back to original data from its time, not by using secondary sources. Such data are scarce. Arguably, texts are the only cultural data that exist in sufficient volume to apply a quantitative approach. Fifth, both Coke and Bacon were prolific scholars. Given the substantial breadth and scope of the authors' opuses, it is hardly surprising that there is a dearth of analyses that compare the two using

conventional methods. Recent advances in computational textual analysis, however, have opened new pathways to such analysis, creating possibilities for the production of new, macroscopic evidence based on the application of machine learning techniques for analysis of large volumes of text.

Our paper thus makes two key contributions to scholarship in economic history and economics more generally. First, our focus on Bacon, Coke, and early seventeenth-century England identifies core elements of a comparatively underexplored emerging culture, which provided a foundation for the subsequent set of ideas and beliefs that stressed the application of scientific methodology to productive use and invention. That eighteenth-century 'culture of growth' (Mokyr 2016) has been viewed as instrumental in England's economic ascent. Our analysis is the first to provide quantitative insight into the main features of the immediately preceding culture, one that was distinctly legal–intellectual in character. Thus, understanding the ideas of Bacon and Coke, two preeminent lawyer-scholars, facilitates comprehension of the full breadth of the intellectual origins of England's economic rise, a paradigmatic example of economic development that has motivated a voluminous literature (e.g., North and Weingast 1989; Mathias 1969; Floud and McCloskey 1994; McCloskey 2006, 2010, 2016; Mokyr 2009; Allen 2009; Clark 2009; Hayek 1960; Moore 1966; North et al. 2009; Acemoglu and Robinson 2012).

Second, our paper illustrates how machine learning can be used productively in the exploration of culture. The study of culture is now more prominent in economics than ever before (Alesina and Giuliano 2015; Guiso et al. 2006, 2016; Barro and McCleary 2003; Nunn 2012; Algan and Cahuc 2010; Tabellini 2008; Bowles and Gintis 2011). Yet unlike humanities scholars (e.g., Newman and Block 2006), economists and social scientists more generally have only recently begun to use the quantitative analysis of text data to investigate the features of salient cultural ideas prevailing at specific points in time (Lucas et al. 2015; Blaydes et al. 2018; Grajzl and Murrell 2019). Within economics in particular, the emphasis to date has been on the 'big data' aspect of text, together with the application of supervised models to create new variables for use in causality-centered regression analyses (see, e.g., Dittmar and Seabold 2016). Our analysis has a different focus: the estimation of an unsupervised model to create a picture of a specific culture that existed at one point in time. This is an approach that has received much less emphasis in the new world of big data and text as input (Gentzkow et al. 2019). But, importantly, it shows the potential of the new techniques to revisit that most traditional of the economic historian's tasks, to characterize the details of a time and place—especially the ideas that then existed. Our approach to the use of machine learning applied to primary text sources could be fruitfully followed in many contexts to examine the shared and divergent elements of culture and intellectual ideas coexisting within a given era.[1]

To set the stage for the analysis, Sect. 2 introduces Bacon and Coke, their backgrounds, and their professional and personal rivalries. Section 3 describes the

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[1] As Gutmann et al. (2018: 283): emphasize: 'Textual data in various forms can provide insight into what past economic actors thought…. Textual corpora provide economic historians with a new quantitative approach to questions sometimes addressed in a more narrative style.'

machine learning technique that we use—the structural topic model (STM)—and the data. Topic modeling is particularly suitable for finding the broad themes present in a large corpus. The algorithms used to estimate topic models are unsupervised. Thus, while the researcher interprets the estimated themes, the estimation of those themes is not influenced by the researcher's preconceived notions. As we elaborate in Sect. 3, STM extends the workhorse Latent Dirichlet Allocation (LDA) model (Blei et al. 2003) in a number of ways, improving the interpretability of the estimated topics and facilitating more reliable estimation of the effects of covariates on topic prevalences (Roberts et al. 2014).

Turning to the heart of our analysis, Sect. 4 presents estimates of the 25 topics that machine learning identifies in the corpus of Bacon's and Coke's writings. These topics are a summary estimate of the core ideas present in English legal–intellectual culture around the beginning of the seventeenth century. In Sect. 5, we use the power of machine learning to investigate the shared foundations of different cultural topics and identify their connectedness. The resulting analysis identifies the central cultural nexuses and their linkages, as evidenced in Bacon's and Coke's works. We detect a shared and perhaps unexpectedly deep, theoretical structure in their legal deliberations, with applications cutting across conventional legal subjects. In Sect. 6, we use STM to provide a first quantitative assessment of the differences and similarities in the emphases present in the writings of Bacon and Coke. While Bacon and Coke differ in their emphasis on particular topics, we find, in contrast to the existing literature, that the similarities between them are as striking as their differences. Importantly, they share a fundamental methodological approach that can be interpreted as a central feature of the era's emerging legal–intellectual thought. Section 7 summarizes our findings more generally and concludes.

2 The rivals in their time

2.1 The background

In the late sixteenth and early seventeenth centuries, English culture was flowering. That period saw the first performances of Shakespeare's plays, the publication of the King James Bible, and early discoveries in medicine and science. It was also an era of competing visions about English institutions. Parliament and the common-law judiciary were increasingly challenging the power of the monarch. In religion, doctrinal and organizational controversies abounded, as debate became more open and the common-law courts challenged the jurisdiction of the ecclesiastical courts.

The common law was establishing its place at the center of English culture (Nenner 1977; Hill 1997; Cromartie 2006). Moreover, the legal profession was becoming an important political and intellectual force. Interactions between monarch and the legal profession were increasingly marked by conflicting conceptualizations of the law and divergent legal philosophies (Berman 1994; Friedrich 1958). For James I especially, law was based on human reason, grounded in the divine right of kings. For common-law lawyers, reason was to be found in both local custom and the

accumulated decisions of generations of learned men in a process akin to trial and error.[2] Francis Bacon (1561–1626), best known as the father of the modern scientific methodology, and Edward Coke (1552–1634), widely recognized as the greatest English lawyer, occupied center stage both intellectually and politically.[3]

Bacon's family was wealthy and politically well-connected. Yet Francis was the youngest of five sons in an age of primogeniture: he needed a profession and he took up the law. In his quest for status and wealth, he gravitated toward service to the monarch. Coke's father had lower social status, but was a successful lawyer in a rich county. As the oldest son, Coke had both financial security and the ambition to follow his father in the law.

Despite these differences in family circumstances, Coke and Bacon were typical of those who entered the country's ruling elite. Both hailed from solid Puritan backgrounds. Both were educated in the humanist tradition and the classics, including rhetoric. Both studied at Cambridge where they were exposed to philosophy and science. Both were thoroughly trained in law at the Inns, England's 'third university,' and both served as practicing lawyers. Both had aspirations to attain the highest professional and political status. They both succeeded.

Young Bacon was a quintessential common-law lawyer (Coquillette 1992). As a member of Parliament, he opposed government-granted monopolies and subsidies to business. He spoke against the crown's encroachment on the right of the Commons to set taxes. He argued that royal grants should be subject to a test of compatibility with judicial and statutory law, in a way in which 'Sir Edward Coke would have been pleased, not just by Bacon's conclusion, but by the technical, and exhaustive, use of common law precedent on which it was based' (Coquillette 1992: 26). Indeed, his views on taxation were one reason why Elizabeth snubbed Bacon in his early attempts to secure higher office.

Bacon's fortunes improved with the ascent to the throne of James I. Upon impressing James with his intellect and after moderating his public statements on matters involving the monarch, Bacon swiftly climbed the professional ladder. He served first as Solicitor General, then as Attorney General, and eventually as Lord Chancellor. After his impeachment for corruption in 1621, he turned nearly exclusively to the study of natural philosophy.

Coke's career followed a different path. Numerous portrayals of Coke as a fearless combatant against royal prerogative often elide the fact that he spent his early years in service of the crown. As Solicitor General and later Attorney General, Coke was absolutely 'ferocious' in his prosecutions against enemies of the monarch, to the extent that 'even his contemporaries were occasionally disgusted' (Holdsworth 1938: 114). Once he assumed the position of Chief Justice of the Court of Common Pleas, however, Coke systematically and persistently voiced his convictions about

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[2] This trial-and-error style was similar to the use of systematic observation and experimentation that had taken root among the practicing artisans, mechanics, and workers of Elizabethan London (Harkness 2007; Hill 1997: 16).

[3] In Holdsworth's (1938: 134) words: 'What Shakespeare has been to literature, what Bacon has been to philosophy, what the translators of the authorized version of the Bible have been to religion, Coke has been to the public and private law of England.'

the supremacy of the law and the corresponding constraints on the government.[4] He continued in this vein throughout the rest of his life, becoming a leader of the Parliamentary opposition after his dismissal from the bench.

2.2 The rivalry

Bacon and Coke had a lifelong professional and personal rivalry. They competed for the hand of the same woman, they vied for top government positions, they tussled over the superiority of the courts that they each headed, and they were opposing lawyers in landmark cases (Burch 1928; Coquillette 1992; Hart 2003). Neither showed any appreciation of the other's intellectual pursuits, except in one instance when Bacon paid, not unalloyed, tribute to Coke's Reports (Gardner 1916; Hollond 1947). Coke, on the other hand, labeled Bacon's work on the foundation of the scientific method as 'sheer folly' (Lyon and Block 1930).

As lawyers, Bacon and Coke were often adversaries.[5] In Slade's case, which fundamentally altered contract law, Bacon and Coke appeared on different sides and their respective advocacy embodied widely different methods and views. Coke's side won the case and Coke's published report completely ignored Bacon's 'learned and persuasive arguments' (Baker 1971: 53; Coquillette 1992: 129, 136).

After he became close to James, Bacon was influential in the decision to transfer Coke from the Court of the Common Pleas to the King's Bench, to reduce Coke's 'capacity for harm' (Holdsworth 1935: 335). Personal antipathies between the two 'no doubt worked as well to exacerbate tensions and hardened positions' (Hart 2003: 103). In 1616, after another dispute, Coke was dismissed from the King's Bench, with Bacon drafting the letter of dismissal. Coke struck back in 1621. As one of the leaders of the Parliamentary opposition, he led the impeachment of Bacon on corruption charges. Through their rivalry, 'Bacon and Coke destroyed each other professionally' (Coquillette 2004: 315).

2.3 The literature

Given the rivalry, it is hardly surprising that the characterizations of Bacon and Coke in the literature are dominated by comments on their differences and contradictions. As Gest (1909: 505) remarked more than a century ago: 'It is indeed hard to estimate correctly…those mighty men who then occupied the center of the stage. Everyone who reads the fascinating Elizabethan story becomes insensibly a Baconian or a Cokean, a partisan of one or the other of those wonderful men.'

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[4] We present here the story that is standard in the historical literature. In a recent historical account, Baker (2017) suggests that Coke was already starting to develop his views on the supremacy of the common law while serving as Attorney General. The story that we present is nevertheless the 'typical historian's verdict' (Baker 2017: 357).

[5] One notable exception was Calvin's case, still influential in citizenship law, where there was much similarity in the positions of Coke, as the Chief Justice of Common Pleas, and Bacon as the King's Solicitor General (Hart 2003: 88).

For some, Coke as 'a technical, skillful and learned lawyer…has never had a superior' (Burch 1928: 10), while Bacon was no more than 'the lawyer without law' (Rogers 1928: 31). For others, even Holdsworth (1935), a great admirer of Coke, Coke had 'a credulity which is as medieval as his law' and his use of history was 'often unhistorical,' while viewing Bacon as the greatest jurist of the day. Wheeler (1983) contrasts 'Coke's antiquarian empiricism' with Bacon's 'rationalist quality that startles us with its modernity.' For Berman (1994), Coke 'articulated no systematic philosophy' and his law had 'no theory at all.' For Coquillette (2004: 312), 'the two men were…philosophical opposites, with very different juristic and ideological beliefs.'

Differences in views on the substantive application of law naturally follow. For Helgerson (2004), 'Bacon favored the king; Coke the law.' Cromartie (1995) characterizes Bacon's maxims as 'authoritarian.' Bacon is even viewed as not in the common-law fold, as a 'civilian' (Kelley 1993) for whom 'his attempted codification of English law was on the French model' (Gaukroger 2006). In contrast, Coke is depicted as 'the greatest oracle of our municipal jurisprudence' and the man 'who afforded a bright example of judicial independence' (Burch 1928: 507).

One can find notable exceptions to this characterization of the literature, but these are rare. For Coquillette (1992: 27), it is necessary to separate 'Bacon's actual views from his advocate's arguments.' Applying this lens, Coquillette argues that Bacon's early work 'had the trappings of a parliamentarian manifesto, and actually read very much like some of Edward Coke's later opinions.' Similarly, de Montpensier (1968: 455) maintains that 'Coke and Bacon shared the same views about the foundations and sources of law, the position of the law and the crown, the relations between the courts and Parliament' and that the differences between them should be understood in light of their varied professional circumstances.

2.4 The task

There are thus two opposing views in the literature on Bacon and Coke, scattered over more than a century of scholarship. There is the near-consensus that Coke and Bacon differed greatly in both general philosophical outlook, legal methods, and substantive application of law. And there is the minority view, expressed by a few scholars, that the two authors shared much in common. We investigate the validity of these contrasting positions using machine learning. In a departure from the existing literature, we do so in an analysis that is explicitly comparative and distinctly quantitative in character.

3 Methods and data

3.1 Structural topic modeling

In order to examine the works of Bacon and Coke, we estimate a topic model. As a complement to conventional textual analysis, topic models are particularly suitable for analyses of large textual corpora when the principal goal of the analysis is to provide a macroscopic guide to the themes emphasized in a corpus. With the

emergence of 'big data' and a growing interest in text-as-data methods, the use of topic models has become increasingly common across a broad range of academic disciplines. The latent Dirichlet allocation (LDA) model (Blei et al. 2003), in particular, has been fruitfully applied by both social scientists and humanities scholars (Grimmer and Stewart 2013: 283–285; Hansen and McMahon 2016; Hansen et al. 2018; Mohr and Bogdanov 2013). Introducing topic modeling to economic historians, Wehrheim (2019) provides a recent overview of research pertinent to the field and offers an application documenting trends in economic history scholarship over time.

Topic models belong to a class of generative probability models that require a researcher to postulate a model of the data-generating process and then use the data to determine the most likely values for the parameters within the model. To estimate the parameter values, topic models view texts as 'bags of words.' An unsupervised machine learning algorithm then exploits the co-occurrence of words across documents to identify 'topics' (Blei 2012). It is important to understand that topic modeling does not simply depend on word counts: topic estimation is driven by correlations of word use across documents. Thus, despite the loss of much syntax that occurs by viewing texts as a bag of words, the semantics of documents can still be reflected, at least partially, in the resultant estimates (Reich et al. 2015).

The resultant topics are formally conceptualized as probability distributions over the corpus vocabulary. Documents (chunks of text) are modeled as mixtures of topics. The name of each topic is assigned by the researcher after scrutiny of the words most closely associated with the topic and study of the documents that feature a given topic particularly prominently. The topics themselves, however, are solely a product of model estimation. In particular, they are not obtained by matching words and documents to concrete thematic issues that are specified by the researcher prior to estimation (as would be the case in a supervised estimation).

We use the structural topic model (STM; Roberts et al. 2014, 2016a, b), the formal statistical structure of which we present in Appendix A[6] (all appendices are available online as part of the electronic supplementary material for this paper). Unlike LDA, STM integrates document-level metadata directly into the estimation of topics and allows topic prevalences to be correlated across documents even when conditioning on the values of the metadata. Intuitively, with documents conceptualized as mixtures of topics, the prevalence of a particular topic will tend to vary across documents because different documents can originate with different authors, or can reflect different time periods, or are intended for different audiences. Thus, rather than estimate topics under the assumption that the corpus documents are fully interchangeable, as implied by LDA, one would like the assumed data-generating process to allow topic prevalences to vary with document characteristics. This is exactly what STM does, thereby enabling the researcher to use document-level variables in the estimation of topics and then subsequently to assess the relationship between these variables and topical prevalence.

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[6] See https://www.structuraltopicmodel.com for a list of published applications of STM.

Roberts et al. (2014: Online Appendix) demonstrate a series of advantages of STM over LDA. The first set of advantages arises because STM tends to improve estimates of the topics themselves. Specifically, simulations show that, in comparison with LDA, STM produces topic estimates that tend to be more exclusive (estimated topics can be better distinguished from each other) and sometimes even more coherent (estimated topics are more internally consistent). STM-identified topics are in general therefore more easily interpretable than LDA-identified topics. In addition, STM-based topic estimates tend to be more robust to the presence of rare words compared to the estimates produced by LDA.

The second set of advantages of the STM arises in the context of the estimation of relationships between topic prevalences and metadata covariates. Estimating these relationships is intrinsic in the structure of STM, but in LDA they would be estimated using a two-stage process where an LDA (without incorporating covariate information) is followed by a conventional regression of LDA-estimated topic prevalences on document-level covariates. Simulated and real data show that STM's full integration of metadata yields both more accurate and more efficient estimates of the covariate effects than does LDA's two-step process.[7]

3.2 The corpus of works

Our corpus merges many works of the two authors. The works of Bacon include all digitized, machine-readable works that could be identified. Our sources for Bacon's works are established repositories of digitized old documents, such as Project Gutenberg (n.d.), Hathi Trust (n.d.), Internet Archive (n.d.), and The Text Creation Partnership for Early English Books Online (2014). Our source of Coke's works is Sheppard (2003), available in electronic format at the Liberty Fund's Online Library of Liberty. Sheppard's anthology is a comprehensive, machine-readable collection of Coke's writings and speeches.

The longer works of each author were broken up into smaller documents in a manual process that used natural breaks in the text. The result was a corpus of 432 text documents of varying length, containing 1,320,262 words, an average of 3,056 per document. Table 1 lists the works included in the corpus. There are more documents from Bacon in the corpus than from Coke. Given an adequately large number of topics to be estimated (see Sect. 4), this feature of the data should not bias the estimated topics in favor of Bacon's works. The reason is that, in estimating the topics, STM does not rely on word frequencies alone, but also leverages the correlation of word use across documents and explicitly allows for topic prevalence to vary with document-level information such as authorship. Thus, as we demonstrate below,

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[7] Specifically, Roberts et al. (2014: Online Appendix) demonstrate that the STM-estimated effects always closely match the true effects, while the two-stage LDA approach often produces estimates featuring incorrect signs. Furthermore, by virtue of incorporating metadata information into topic estimation, STM estimates of covariate effects have smaller confidence intervals than those of LDA estimates. Using permutation analysis, Roberts et al. (2014: Online Appendix) also show that STM-based incorporation of metadata into topic estimation does not introduce spurious relationships between topic prevalences and metadata covariates.

despite the fact that Bacon's works are more prevalent in the corpus than Coke's, a number of topics are featured highly in the documents of both Bacon and Coke, with a further set of topics dominated by either Coke or Bacon.

The documents were processed in a series of steps that converted the chaotic orthography of late sixteenth- and early seventeenth-century English into standard modern orthography and to translate Latin words into English. Appendix B summarizes the details of the processing and also provides evidence in favor of considerable success in standardizing the orthography across the corpus. The corresponding analysis also indicates that potential OCR issues are not a concern for our analysis.

The resultant corpus was imported into R using the stm package. To prepare the corpus for estimation, further text processing was implemented using R's textProcessor function. All words were converted to lower case. The Porter stemming algorithm was applied. Standard English stop words (natural language words with little meaning, such as 'and,' 'the,' 'a,' 'an'), numbers, and punctuation were removed. The resulting dataset consists of 432 text documents and 215,556 word tokens.

3.3 Metadata

The last step in organizing the data was to assign values of metadata variables to each document. We coded four metavariables: authorship (Bacon or Coke), intended audience (lawyers, politicians, historians, methodologists, philosophers, or scientists), form of finished work (essay, case report, apothegm, book-length tome, letter, or speech), and year of completion. Table 2 provides the document frequencies within each cell of the metadata variables.

The authorship and the form of finished work were readily ascertained. The coding of intended audience was based on scrutiny of each document while simultaneously taking into account existing scholarship on Bacon and Coke. The stated intentions of the authors or the substance of the documents were very important for this coding. For example, the prefaces of Coke's *Reports* were obviously not intended to bolster the legal record but were rather a guide to the methodology that Coke used in writing the reports. Similarly, the letters of Bacon could be easily divided into ones that were in the political or legal sphere and ones advancing his philosophy. Note that for intended audience, the monarch was classified as a politician, since communications with the monarch invariably concerned matters of state.

The year of completion was coded by taking into account any available information about the lives of the two authors. For the vast majority of documents in the corpus (69%), we were able to ascertain the exact year of publication. When no additional information about the timing of a work was available, for works published in the author's lifetime we took the year of the work's publication as the year of the work's completion. However, some of Bacon's and Coke's works were published only posthumously or the exact year of their completion is unknown. For those documents (31%), we conducted a thorough search of available sources about the author's work and life in order to identify the earliest possible and the latest possible year of completion. To fix a single year for completion, for each document we separately drew a random integer from the interval of possible years. For those works for

Table 1 Works included in the corpus

Name or type of work	Author	Document count
New Atlantis	Bacon	5
Novum Organum	Bacon	17
The Advancement of Learning	Bacon	12
The Use of the Law	Bacon	5
A Collection of Apothegms, New and Old	Bacon	6
History Natural and Experimental of Life and Death	Bacon	9
Sylva Sylvarum	Bacon	10
The History of The Reign of King Henry the Seventh	Bacon	6
The Natural and Experimental History of Winds	Bacon	7
The Wisdom of the Ancients	Bacon	5
The Elements of the Common Laws of England	Bacon	28
Bacon's other writings (essays, letters, speeches, case reports)	Bacon	172
The Reports, Part One	Coke	2
The Reports, Part Two	Coke	4
The Reports, Part Three	Coke	3
The Reports, Part Four	Coke	5
The Reports, Part Five	Coke	9
The Reports, Part Six	Coke	2
The Reports, Part Seven	Coke	4
The Reports, Part Eight	Coke	4
The Reports, Part Nine	Coke	4
The Reports, Part Ten	Coke	3
The Reports, Part Eleven	Coke	5
The Reports, Part Twelve	Coke	22
The Reports, Part Thirteen	Coke	2
The First Part of the Institutes, or a Commentary upon Littleton	Coke	32
The Second Part of the Institutes	Coke	17
The Third Part of the Institutes	Coke	9
The Fourth Part of the Institutes	Coke	11
Coke's other writings (essays, speeches)	Coke	12
Total number of documents for Bacon		282
Total number of documents for Coke		150
Total number of documents in the corpus		432

The names of some of the works have been edited for rendering in modern English

which the year had to be estimated, the mean absolute value of the error would be less than five years. None of our substantive conclusions would change with a more precise estimate of dating. Appendix C provides full details on the dating process.

Table 2 Frequency of documents by author, form of finished work, intended audience, and time period of completion

Panel A: Documents by form of finished work

Form of finished work	Bacon	Coke	Total
Essay	95	84	179
Case report	2	56	58
Apothegm	34	0	34
Speech	14	10	24
Tome	76	0	76
Letter	61	0	61
Total	282	150	432

Panel B: Documents by intended audience

Intended audience	Bacon	Coke	Total
Lawyers	74	131	205
Politicians	58	7	65
Historians	14	3	17
Philosophers	50	0	50
Methodologists	39	9	48
Scientists	47	0	7
Total	282	150	432

Panel C: Documents by time period of completion

Time period	Bacon	Coke	Total
Prior to 1590	0	6	6
1590–1599	52	11	63
1600–1609	67	38	105
1610–1619	63	39	102
1620 or later	100	56	156
Total	282	150	432

Bacon lived 1561–1626. Coke lived 1552–1634

4 Estimating and interpreting topics

The first decision to be made in estimating an STM is on the number of topics. Because there exists no standard approach on this decision (Roberts et al. 2014, 2016b), we estimated a series of models, with the number of topics varying between 15 and 30. We examined measures of their goodness of fit such as held-out likelihood and size of residuals (Wallach et al. 2009; Taddy 2012; Roberts et al. 2016b). We then compared the set of models that fit the data especially well by using the models' scores for average semantic coherence (indicative of the internal consistency of the topics) and exclusivity (indicative of the extent to which topics in the model can be distinguished from each other). We thereby identified the subset of models on the semantic coherence-exclusivity frontier (Roberts et al. 2014). We

inspected the cohesiveness and exclusivity of the topics for these models using our own judgment. This process led to the selection of a model with 25 topics. We verified that all of our substantive findings were robust to small variations in the number of topics.

After naming the topics in a process to be described below, we grouped them into seven general themes to organize our initial findings. Table 3 provides a first, broad overview by listing names for the general themes, the topic names, and a measure of the relative importance of each author for each topic. The table arrays the topics on a natural continuum beginning with law in the abstract and then proceeding via substantive law, to politics, science, and the scientific method.

The organization into themes is based on our a priori conception of which topics belong in standard categories. However, one of the properties of STM is that it is not constrained by a priori notions: it can find unexpected patterns in the data. Thus, when such patterns are examined in the following section, we show how STM offers a slightly different organization of the topics than that in Table 3, improving upon our a priori conceptions and, importantly, offering novel insights about the corpus. For example, STM shows quite clearly that topics can be placed on a circular continuum rather than a linear one: there is a strong connection between the first and the last topics in Table 3.

Table 4 lists the words most strongly associated with each topic. These words are a product of the estimation and are therefore word stems (e.g., 'judg'). Choosing topic names involves examining in which documents a given topic is most prominent and which words are most strongly associated with each topic. Table 4 provides two lists of the top 30 words for each topic. The highest probability ('Highest prob') words are those most common for a given topic, but are also non-exclusive—they might be the highest probability words for several topics. 'FREX' words are used more frequently in documents highly associated with a topic.[8] For brevity, we use the shorthand of 'ranked highly' or 'top' when referring either to documents that feature a given topic prominently or to words ranked high by either of the two above criteria.

The assignment of names to topics is central in the analysis because our general conclusions rest upon being able to interpret the content of each topic. Thus, it is notable that we could easily identify the ideas underlying each topic. Moreover, our topic names resonate strongly with concepts in the legal, historical, and traditional text analysis literature. The paragraphs below present examples of the arguments used to choose topic names. We stress that the focus is on examples because space limitations prevent the inclusion of the voluminous evidence we considered in justifying the choice of each topic name.

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[8] We restrict the FREX words to those used with some frequency in order not to focus on unusual words that are used once in a document. Our choice of FREX words is characterized by a frequency to exclusivity ratio of 0.25 (see Roberts et al. 2016b).

Table 3 Themes, topics, and authorship

Themes and topics	% top 50 documents by Bacon
Legal scholarship	
Understanding Law	14
Jurisprudence	54
Disambiguating Law	50
Private law	
Property Rights	28
Land Inheritance Law	30
Private/public law	
Religion, Law, & Truth	50
Defendant Rights	28
Regulation of Exchange	22
Public & Private Authority	10
Public law	
Legal Jurisdiction	10
Criminal Justice System	34
Constitutional Law	0
King, Law, & Nation	82
Politics	
King & Court	96
Dynastic Politics	84
Foreign Relations	92
Civic Knowledge	100
Science	
Human Nature	96
Botany	100
Pharmacology	100
Physics, Air & Sound	92
Physics, Energy	94
Methodology	
Extracting Meaning	100
Probing For Facts	92
Epistemology	100

% top 50 documents by Bacon refer to the percent of the 50 documents featuring a given topic most prominently that are authored by Bacon (as opposed to Coke)

4.1 Legal scholarship

Both Bacon and Coke are prominent in the topics that capture different dimensions of legal scholarship. The first topic focuses on Understanding Law (we capitalize the topic names, to easily identify them). 'Law' is the most used word, while 'book,' 'student,' 'reader,' 'professor,' 'treatis,' 'commentari,' and 'inn' are all highly ranked

Table 4 Topics and top words for the estimated 25-topic STM

Understanding Law

Highest Prob: law, king, time, say, case, great, court, justic, book, man, mani, shall, may, will, author, one, make, year, learn, ancient, first, england, common, reign, part, commonlaw, call, statut, observ, judg

FREX: prefac, student, sage, conqueror, demurr, reader, professor, treatis, commentari, inn, dom, justinian, forest, herein, institut, client, compil, confessor, reign, reverend, conquest, sergeant, greek, advoc, cite, edit, publish, lawyer, judici, cautious

Jurisprudence

Highest Prob: use, statut, shall, law, feoff, make, upon, case, will, land, estat, seiz, may, word, therefor, act, take, yet, say, life, first, can, time, right, possess, fine, good, heir, tenant, give

FREX: cesti, feoff, entail, covin, lesse, feme, lessor, remaind, statut, use, disseise, remit, proviso, seiz, leas, formedon, levi, fraud, bargain, convey, atturn, remitt, conting, estat, tenanc, asset, surrend, trust, revers, stranger

Disambiguating Law

Highest Prob: shall, land, grant, king, word, deed, pass, one, name, man, may, make, take, call, yet, say, law, year, upon, non, wit, can, signifi, give, time, place, therefor, rule, rend, hold

FREX: domesday, ambigu, praecip, deed, estov, dale, meadow, acr, widow, aver, quarantin, revoc, signifi, revok, pastur, arbitra, falsiti, terra, liveri, injust, papyrus, detractor, moieti, habendum, oblig, rei, promontori, date, style, oblige

Property Rights

Highest Prob: heir, shall, say, case, land, edward, son, purchas, make, estat, law, use, take, man, can, bodi, shelley, tail, issu, word, therefor, male, execut, may, life, yet, tenant, will, first, hold

FREX: shelley, vest, male, tail, ventur, escheat, homag, recoveri, purchas, recoveror, elder, advowson, indentur, forasmuch, haer, fol, divest, beneficiari, reenter, sue, leas, escuag, remaind, bastard, heir, ancestor, jane, fealti, feesimpl, donor

Land Inheritance Law

Highest Prob: heir, land, shall, son, inherit, father, law, blood, die, issu, part, man, brother, old, mother, seiz, make, feesimpl, without, descend, author, enter, case, descent, can, littleton, daughter, call, fee, purchas

FREX: inherit, brother, blood, father, mother, uncl, cousin, descent, heir, section, sister, littleton, descend, son, feesimpl, issu, daughter, lineal, attaint, soccag, attaind, die, guardian, haered, collater, freehold, sex, maxim, albeit, parent

Religion, Law, & Truth

Highest Prob: god, church, man, say, law, will, may, shall, great, time, good, thing, upon, bishop, know, case, matter, word, part, can, one, holi, first, work, yet, true, see, mani, religion, publish

FREX: preach, controversi, church, uniti, preacher, holi, christ, ghost, etern, liturgi, worship, libel, publish, scriptur, ministri, sermon, pastor, reveal, apostl, saviour, atheist, profan, primit, prayer, scandal, baptism, chariti, god, sin, censur

Defendant Rights

Highest Prob: law, say, shall, man, king, will, may, case, upon, hous, caus, give, edward, make, justic, can, take, without, imprison, judg, reason, non, defend, good, parti, great, one, time, arrest, action

FREX: arrest, etcetera, loan, corpus, imprison, pillag, habea, april, detain, verdict, grievanc, num, bail, breve, magnacarta, atia, prison, martial, warrant, forethink, barg, passeng, assumpsit, march, june, malic, excus, indict, stanford, felon

Table 4 (continued)

Regulation of Exchange

Highest Prob: shall, good, land, man, may, make, custom, debt, king, will, take, upon, one, say, court, prescript, time, can, everi, pay, day, call, manor, lord, sheriff, parti, within, give, justic, use

FREX: swan, prescript, debt, pledg, eyr, tourn, usuri, executor, franchis, prescrib, legaci, leet, chattel, creditor, properti, owner, pay, sewer, copyhold, manor, circuit, rate, forfeit, bank, satisfact, sale, recogniz, shop, market, sheriff

Public & Private Authority

Highest Prob: say, king, shall, make, case, act, aforesaid, grant, henri, may, law, word, edward, time, can, one, caus, without, hospit, incorpor, good, give, hous, upon, plaintiff, well, borough, within, patent, resolv

FREX: hospit, borough, colleg, sutton, censor, disfranchis, aforesaid, monopoli, mayor, incorpor, burgess, plymouth, bag, jame, licenc, art, card, chantri, commonalti, thoma, patent, governor, ordin, trade, dispens, physic, sole, rectori, partnership, corpor

Legal Jurisdiction

Highest Prob: king, law, say, england, court, shall, case, one, henri, upon, allegi, subject, edward, may, justic, judg, natur, can, make, appear, bear, plea, writ, caus, protect, statut, prohibit, cap, act, within

FREX: allegi, protect, prohibit, tith, praemunir, calvin, pendent, fol, ecclesiast, alien, modus, gascoin, obedi, plea, jurisdict, cannon, cogniz, lieg, extra, municip, surmis, born, deniz, cap, spiritu, bracton, lib, dominion, parson, headway

Criminal Justice System

Highest Prob: king, treason, act, shall, statut, law, case, say, justic, man, feloni, make, high, indict, upon, may, lord, take, person, offenc, word, parliament, realm, within, court, judgement, punish, give, death, can

FREX: treason, mispris, indict, feloni, peer, steward, constabl, heresi, accus, offenc, gaol, overt, heret, convict, counterfeit, guilti, arraign, sorceri, accessari, abjur, punish, purvien, petti, offend, conspiraci, murder, roy, oier, witchcraft, traitor

Constitutional Law

Highest Prob: king, parliament, lord, hold, common, say, shall, make, writ, edward, henri, come, act, year, call, statut, per, great, law, may, time, custom, realm, baron, grant, one, england, quoth, take, appear

FREX: tunnag, subsidi, baroni, frankpledg, parliament, imposit, poundag, wool, concilium, summon, men, baron, elig, abbot, burgess, assent, holiday, johann, roll, chapter, alnag, relief, comitatus, ibidem, comrad, prorog, diem, print, realli, testa

King, Law, & Nation

Highest Prob: law, shall, will, may, king, majesti, england, one, natur, kingdom, subject, make, time, first, therefor, can, scotland, unto, peopl, part, sever, yet, great, person, now, point, question, take, upon, parliament

FREX: plantat, scotland, union, speaker, papist, kingdom, britain, nation, unit, vote, sovereignti, gascoign, majesti, seminari, recus, monarchi, submiss, jesuit, abus, committe, pope, born, provinc, territori, hostil, scottish, foreign, nobil, ireland, excommun

King & Court

Highest Prob: majesti, will, shall, may, good, time, lordship, lord, upon, great, think, make, can, self, king, now, know, give, god, well, honour, yet, take, man, thing, letter, matter, much, place, though

FREX: lordship, majesti, humbl, gracious, essex, hope, pleas, solicitor, acquaint, revenu, wish, letter, thank, honour, honest, care, con, glad, happi, remembr, beseech, crave, unworthi, duti, messag, secretari, vouchsaf, advic, callisthen, presum

Table 4 (continued)

Dynastic Politics

Highest Prob: king, upon, make, great, will, time, shall, come, may, man, part, take, person, one, peopl, war, yet, also, unto, good, well, think, lord, much, give, princ, england, can, duke, two

FREX: maximilian, perkin, ferdinando, treati, flander, duke, castill, charl, ambassador, rebel, york, margaret, ladi, plantagenet, fillip, britain, french, lovel, earl, bruge, stanley, ambassag, succour, sanctuari, napl, burgundi, duchess, thousand, clifford, calai

Foreign Relations

Highest Prob: upon, great, war, make, man, spain, will, time, state, king, shall, yet, say, may, one, part, law, take, england, princ, come, peopl, now, like, though, much, true, mani, never, nation

FREX: spain, lopez, spaniard, invas, squir, spanish, portug, cathol, war, turk, antonio, duel, enterpris, pollio, manuel, nation, valour, christendom, design, indi, armi, quarrel, confeder, leagu, lowcountri, germani, libel, palatin, navi, sundri

Civic Knowledge

Highest Prob: man, good, will, make, great, say, upon, may, thing, time, one, can, much, natur, well, shall, like, see, yet, person, mind, take, mani, use, virtu, therefor, come, first, part, fortun

FREX: envi, tacitus, caesar, felic, cicero, fortun, bewar, faction, anger, dissimul, demosthen, solomon, sulla, reprehens, virtu, secreci, discours, convers, lover, precept, machiavelli, poverti, discontent, cun, seneca, perturb, tiberius, malum, busi, proverb

Human Nature

Highest Prob: man, shall, will, upon, make, great, may, thing, one, come, say, think, also, work, take, give, imagin, good, day, time, place, let, see, thou, yet, like, god, mani, can, natur

FREX: thi, ointment, imagin, witch, galleri, bensalem, inventor, thou, boat, belief, bead, magic, pillar, travel, jew, miracl, wart, earthquak, front, room, plagu, perfum, herald, sick, delug, scroll, hebrew, dream, blue, remnant

Botany

Highest Prob: tree, will, upon, plant, fruit, make, earth, may, water, put, grow, ground, caus, come, root, also, forth, like, flower, great, herb, seed, leav, set, see, bear, kind, one, therefor, sun

FREX: sap, plum, bough, cherri, pear, stalk, graft, herb, oak, tree, holli, moss, peach, dung, fig, elm, radish, plant, cucumb, blossom, onion, appl, lettuc, earli, rosemari, flower, fruit, mushroom, colewort, mistleto

Pharmacology

Highest Prob: bodi, spirit, will, part, water, may, make, thing, also, see, upon, long, caus, air, heat, great, man, much, therefor, like, take, live, use, time, good, natur, cold, littl, motion, one

FREX: liquor, tooth, intener, oil, nitr, aliment, stomach, amber, explic, opiat, putrefact, beer, spirit, saffron, consumpt, decoct, refriger, bottl, opium, sweat, sugar, cool, liver, indur, diet, flesh, dri, repar, malaciss, purger

Physics, Air & Sound

Highest Prob: wind, sound, air, will, make, one, may, blow, thing, great, motion, water, bodi, part, upon, see, like, likewis, much, also, caus, sail, come, place, shall, man, sea, yet, can, two

FREX: wind, string, echo, sail, sound, tone, brass, rain, percuss, blow, pipe, mast, south, nois, east, bell, concav, articul, cloud, north, dram, lute, engend, audibl, air, presag, gale, nurseri, metal, diapason

Physics, Energy

Highest Prob: motion, heat, bodi, natur, instanc, will, water, air, must, also, may, fire, can, place, let, part, first, one, like, cold, substanc, yet, flame, great, observ, differ, spirit, power, appear, shall

FREX: magnet, similar, instanc, howev, expans, anim, rapid, heat, investig, latent, predomin, liquid, tendenc, exist, excit, ebb, ray, heterogen, homogen, expand, conspicu, migrat, perpendicular, ignit, flame, format, motion, concret, subjoin, exclus

Table 4 (continued)

Extracting Meaning

Highest Prob: man, thing, year, life, may, live, age, natur, also, one, long, yet, hundr, great, say, shall, will, time, see, seem, mani, unto, god, make, like, mind, old, well, can, neither

FREX: nineti, jupit, prometheus, pan, eighti, proserpina, fabl, orpheus, parabl, page, miss, nemesi, siren, typhon, muse, pentheus, sphinx, perseus, youth, giant, bacchus, cupid, palla, cere, vicissitud, hundr, moreov, seventi, eleg, atalanta

Probing for Facts

Highest Prob: say, will, lord, man, one, upon, king, shall, great, come, answer, make, give, take, may, sir, can, time, first, day, know, like, queen, thing, tell, ask, much, think, overburi, see

FREX: overburi, impoison, somerset, weston, bacon, ask, poison, vespasian, diogen, slander, aristippus, peacham, madam, pompey, aggrav, injunct, pillow, tell, ladi, gentleman, forgiv, seaman, displac, chanceri, cardin, captain, sir, raleigh, answer, alexand

Epistemology

Highest Prob: natur, man, thing, will, may, philosophi, knowledg, histori, use, part, one, scienc, great, mind, can, make, upon, yet, shall, experi, therefor, learn, matter, first, much, caus, particular, work, true, find

FREX: philosophi, defici, scienc, histori, method, logic, system, aristotl, axiom, metaphys, idol, everyth, contempl, discoveri, inquiri, rhetor, notion, theori, knowledg, abstract, mathemat, theolog, mankind, principl, poesi, deduc, sophist, plato, intellectu, subtleti

The 'words' listed in the table are those used by STM after reducing all original text words to their stemmed form. Thus, for example, 'possess' could reflect an original usage of possess, possesses, possession, possessing, possessed, possessions, etc.

in this topic and not elsewhere. A majority of the top twenty documents are Coke's prefaces or conclusions. Coke's concern in these documents is to point out that the purpose of his Reports is not simply for readers to learn about the law, but 'to understand what the true sense and sentence of the Lawes then standing is.'[9] For Coke, the texts are intended to be useful even for the highest levels of the legal profession: '… But forasmuch as if a man should spend his whole life in the study of these Lawes, yet he might still add somewhat to his understanding of them.'[10] Similarly, for Bacon: 'Concerning the Lawes of England: They commend themselves, best to them, that understand them.'[11]

The second topic reflects Jurisprudence, or analytical legal theory, again spanning various areas of substantive law. The most prominent words are 'law,' 'statut,' and 'case,' while among the FREX words are 'cesti' (beneficiary), 'entail,' 'covin' (fraud), and 'proviso' (clause), all with specialized meanings in distinct areas of law. The highest ranked document for this topic is Bacon's 'Reading upon the Statute of Uses,' a scholarly analysis of a controversial sixteenth-century property-law statute. A number of Bacon's *Maxims* are also highly ranked, each maxim intended to be an analytical statement of the principles of law relevant to widely varying substantive areas. Coke also figures prominently. The tenth-ranked document is Coke's report

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[9] In the preface to Coke's fourth reports.
[10] In the preface to Coke's third reports.
[11] In 'A Proposition Touching the Compiling and Amendment of the Lawes of England.'

on Heydon's case, a landmark of statutory interpretation, in which Coke advised '…that for the sure and true interpretation of all statutes in general…restrictive or enlarging of the Common Law, four things are to be discerned and considered.'

Disambiguating Law focuses less on general principles and more on clarifying specific legal doctrines. 'Ambigu' appears as a highly ranked FREX word here, and not elsewhere, reflecting this topic's focus on removing ambiguities in legal rules. Among the most prominent documents are several of Bacon's *Maxims*, which were set down '…so that the uncertainty of law…be somewhat the more settled and corrected.'[12] For example, Bacon's twenty-third maxim is ranked fifth: 'Hidden ambiguity of words may be supplied by proof; for an ambiguity arising from facts is removed by proof of the facts.' Coke is also prominent. In the eighth ranked document he advises: '…to set down in conveyances everything in certainty and particularity, for Certainty is the mother of quietness and repose, and uncertainty the cause of variance and contentions.'[13]

4.2 Private law

One topic addresses Property Rights in general. Among the words distinctive to this topic are 'vest,' 'escheat' (reverting of property to the crown), 'purchas,' 'beneficiari,' 'advowson' (the right to present a candidate for a church office), 'recoveri,' and 'escuag' (the military service consequent on a knight's land use rights). The topic is dominated by property in land, but although property in land usually provides the context, the discussion in the top documents is often conducted in terms of more general property rules and rights. For example, one such document expounds on the rights of tenants and landlords over a rented house, another focuses on how Magna Carta specifies the rights and obligations of those who control properties.

A closely associated topic is the one that focuses on Land Inheritance Law. Inspection of the associated words is sufficient to establish its name. 'Heir,' 'land,' 'shall,' 'son,' 'inherit,' 'father,' 'law,' 'blood,' 'die,' and 'issu' are the highest probability words. The top documents have a similar cast. The one non-legal document is Bacon's essay on parents and children that concludes with 'Younger brothers are commonly fortunate, but seldom or never where the elder are disinherited.' Many of the top documents are from Coke's commentary on Littleton, but there are also case reports: Shelley's case provides a rule on the inheritance of estates and Lord de la Warre's case clarified laws of inheritance.

4.3 Private–public law

In seventeenth-century England, the institutionalization of society proceeded apace, with the boundaries between private and public gradually becoming delineated. Not surprisingly then, a number of topics span both public and private law. Religion, Law, & Truth reflects the most pressing of these areas of contention. The top FREX

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[12] In the preface to Bacon's Maxims.
[13] In the first volume of Coke's Institutes.

words speak collectively to the substantive issues: 'preach,' 'controversi,' 'church,' 'uniti.' But 'law' is also among highest probability words and fifteen of the top twenty documents are about law, with 'true' or its variants prominent in those documents. One top document is Lord Cromwell's Case, on slander in a highly politicized religious setting.

The mixture of religion and the ascertaining of truth in general, often through the use of the law, is best indicated for this topic by uses of the word 'reveal,' one of the top FREX words for this topic and only this topic. Coke states that the revelation of the truth is the purpose of his reports.[14] In a highly ranked section from his great methodological work *The Advancement of Learning*, Bacon wrote: '…I note this deficiency, that there hath not been…sufficiently inquired and handled the true limits and use of reason in spiritual things…to search and mine into that which is not revealed.' This hints at Bacon's epistemology of eliminative induction, for which he is most renowned. Similarly, in top documents, Coke clearly states his modes of reasoning. For example, in the preface to the sixth volume of his reports, Coke comments 'That if the ancient Laws of this noble Island, had not excelled all others… some of the several Conquerors and Governors thereof…would (as every of them might) have altered or changed [these laws].' This is an example of a general evolutionary mode of argumentation, which was characteristic of the common law at that time (Grajzl and Murrell 2016).

Interestingly, Religion, Law, & Truth and Epistemology, which is introduced below, are the only two topics for which 'true' is a highly rated word. Moreover, a majority of the documents most highly associated with Religion, Law, & Truth have the two authors focusing on the structure of arguments that should be applied to religion and to doctrinal and church-organization issues.[15] These are often, but not always, legal arguments. At the current level of analysis, therefore, it is simply not clear to what extent Religion, Law, & Truth is a topic about the application of law to religion versus a topic about methods of argumentation that happen to be often applied to religion and law. Fortunately, STM has techniques in its toolbox that will cast light on this issue. We make us of those techniques in the following section.

Defendant Rights focus on law that establishes the rights of defendants in criminal trials and the defenses possible in civil suits. Thus, words prominent in this topic are 'imprison,' 'magnacarta,' 'habea,' 'corpus,' and 'bail,' but also 'assumpsit' and 'loan,' which are relevant to civil matters. All the top five documents are Coke's case reports. Semayne's Case concerns when an official can legally break into a house; Vaux's Case clarifies double jeopardy; and William Aldred's Case elucidates when

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[14] The tenth report's preface states: 'This part containeth a true and just Report…to avoid that, which venerable Verity [truth] doth blush at for fear, that is, that she which is the Foundation of Justice should not be hidden and unknown. Neither is she pleased, when once she is found out and revealed to be called into argument and question'd again, as if she were not in Verity indeed.'

[15] It is not surprising that the form of argumentation should be important to the two authors in these substantive areas. Religion was at the fulcrum of English politics throughout the two centuries in which Bacon and Coke lived. Debate about religious issues was becoming more open and more intertwined with the law as the common-law courts wrested jurisdiction from the ecclesiastical courts. But such debate was risky, with blasphemy still a capital offense; therefore focusing on details of the method of argumentation would be a safer strategy than articulating one's convictions.

an act constitutes a nuisance, containing the memorable dictum that 'one ought not to be of so delicate nosed, that he cannot endure the scent of hogs.' Bacon's *Maxims* are also highly ranked, the fifth on the impossibility defense; the seventh on motive and extent of damage in criminal and civil cases; and the twenty-second on duress.

The next topic also covers heterogeneous substantive areas. The top documents are all legal ones, but there is no 'law' among the most common words. This paradox suggests that the topic concerns matters that legal authorities often wanted to comment on, but for which formal law was less important. There are many FREX words that refer to market relationships: 'debt,' 'franchis,' 'pay,' 'sale,' 'chattel' (movable property), and 'rate.' Bacon's *The Use of the Law* is prominent, examining the varied ways to obtain property in goods, including mechanisms other than markets. The third ranked document is Coke's report on market-overt, explaining how custom regulates ownership of stolen goods. Bacon's essay on usury uses moral, legal, and economic arguments. Highly ranked documents consider taxes imposed on the beneficiaries of drainage projects and the giving and taking of property for religious purposes. This topic, then, is about the variety of institutional and cultural mechanisms that could support exchange. We use the rather modern name, Regulation of Exchange.

As noted above, the separation between the public and private spheres was central in seventeenth-century political struggles. Public & Private Authority captures elements of these struggles. It is all Coke, with the highest ranked documents all legal cases. Among these are rulings on when the state can make a monopoly (Case of Monopolies); on when restrictions on trade are lawful (The Chamberlain of London's Case); on the powers of town governments (James Bagg's Case); on the legal authority of an arbitrator (Vynior's Case); on the creation of an official office to benefit a private citizen (Walter Chute's Case); on the power of private bodies to implement taxes for use of public works (The Case of the Isle of Ely); and on whether the King can dispense with the law for particular individuals (The Case of Non-Obstante).

4.4 Public law

We label the next topic Legal Jurisdiction; indeed, 'jurisdict' is among the top FREX words. It focuses on specifying which institutions and organizations have which powers and obligations. The highest ranked document is Langdale's case concerning intercourt jurisdiction; second is the case of Praemunire, concerning the sphere of ecclesiastical and temporal courts (and ultimately the authority of foreign powers within the Kingdom). Ranked next is Fuller's case in which 'It was resolved when there is any question concerning what power or jurisdiction belongs to Ecclesiastical Judges…the determination of this belongs to the Judges of the Common Law….' Ranked fourth is Calvin's case, concerning the jurisdiction of English law for Scottish citizens, the two countries being separate nations with a common monarch. Other highly ranked documents address jurisdictional disputes between the Court of Common Pleas and the Court of the Admiralty, between the Crown and courts, and between different local officials.

Next is a topic on the Criminal Justice System. The top five documents are all from the third part of Coke's *Institutes*, which examines '…De malo, viz. of High Treason, and other Pleas of the Crowne, and Criminall Causes….' Bacon is also prominent, his 'Cases of Treason' covering a broad range of crimes, together with the organization of the courts dealing with them. This is consistent with the types of words that are ranked highly: 'indict,' 'court,' 'punish,' 'steward,' 'constabl,' 'accus,' 'offenc,' 'gaol,' 'arraign,' etc. In other top-ranked documents, Coke reports on the case of Floyd and Barker, which concerned the conduct of criminal proceedings, and Bacon's *The Use of the Law* lays out the purpose and logic of different adjudicatory and law enforcement institutions. This topic is clearly about both criminal law and criminal procedure.

Constitutional Law is almost entirely a product of Coke. Prominent are elements of the fourth part of the *Institutes*, reviewing such topics as the powers of the courts, the law and custom of parliament, the monarch's rights in religion, Parliamentary control over taxation, rules on elections, stipulations on who can sit in Parliament, etc. Consistently, there are a number of distinctive words that are highly associated with this topic and not with others: for example, 'tunnag,' 'subsidi,' 'frankpledg,' 'imposit,' 'poundag,' and 'alnag' all refer to issues of taxation.

In contrast, King, Law, & Nation is dominated by Bacon. A large proportion of the FREX words refer to aspects of nationhood or monarchy (e.g., 'union,' 'papist,' 'kingdom,' 'nation,' 'sovereignti,' 'territori'). The highest probability word is 'law' but the topic goes beyond law. A top-ranked document discusses the way in which a King should approach decisions.[16] Another is a letter to one of the King's favorites advising what (extra-legal) powers the recipient has and how he should conduct himself.[17] This topic reflects both Bacon's legal training and his background in Renaissance humanism, with its emphasis on the connection between improved knowledge and good government.

4.5 Politics

On the continuum of themes, we now move from law into politics. Legal terminology is absent from the most used words, while royal and aristocratic terms are prominent. King & Court focuses on the monarch's role in government and interpersonal relations in his court. Most of the documents that are strongly associated with this topic are Bacon's letters, most referring to court politics. Sometimes the politics is of a very personal kind, with Bacon revealing his most unctuous self in pleading for personal favors.

The top documents for Dynastic Politics are Bacon's histories of the reigns of the three great Tudor monarchs and letters from Bacon that use lessons from history to advise others. Coke is not absent here: three of the top twenty documents are his.

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[16] 'An Essay of a King.'
[17] 'A Letter Of Advice Written By Sr Francis Bacon To The Duke Of Buckingham.'

These have a similar tenor: all three use historical examples to elucidate the author's points on a variety of political and legal questions.

The next topic is easily labeled by looking at the top ten FREX words: 'spain,' 'lopez,' 'spaniard,' 'invas,' 'squir,' 'spanish,' 'portug,' 'cathol,' 'war,' 'turk.' This is Foreign Relations, and it is all Bacon. In the documents most associated with this topic, there is discussion of a war with Spain, an analysis of just wars, a deliberation of what makes kingdoms great (arms), ruminations on the appropriateness of a holy war, observations on the foreign causes of internal problems, and a speech in parliament on the necessity of raising taxes to increase the external strength of England.

Civic Knowledge is the topic in which Bacon's background in Renaissance humanism comes to the fore. All top twenty documents are his essays, except one, a section of *The Advancement of Learning* that is exclusively about 'civil knowledge.' The words particularly associated with the topic are primarily of two kinds, mental dispositions—'envi,' 'felic,' 'bewar,' 'anger,' 'dissimul,' 'virtu,' 'secreci,' 'discontent,' 'cun,' 'perturb,' 'malum'—and historical figures used to motivate the discussion—'tacitus,' 'caesar,' 'cicero,' 'demosthen,' 'solomon,' 'sulla,' 'machiavelli,' 'seneca,' 'tiberius.' This topic focuses on discussing the states of mind that are relevant in civic action and on the process of detecting them in others. It is not a methodological topic, but rather an application of ideas on human nature to the civic world.

4.6 Science

This theme solely reflects Bacon's science (or natural philosophy). There are five topics, four of which have little interest for this paper, but the first is thematically related to those discussed before. This topic is Human Nature, where Bacon attempts a natural philosophy of psychology. Among the highest probability words are 'man,' 'imagin,' and 'natur.' FREX words include 'dream,' 'belief,' and 'magic.' In the large variety of documents that are associated with this topic, the common thread is the workings of the human mind, the erroneous patterns of thought that must be excised, and the qualities of human thinking that are to be admired. Bacon's prayers ask for the 'unlocking of the gates of sense, and the kindling of a greater natural light' to create a 'mind, thoroughly cleansed and purged from fancy and vanities.' The essay on adversity is a disquisition on how human nature is formed, 'for prosperity doth best discover vice, but adversity doth best discover virtue.' Bacon's most enigmatic work, *The New Atlantis*, features this topic prominently, with its inclusion of many comments on the exercise of the mind: 'let us know ourselves,' 'every man reform his own ways,' 'the knowledge of causes,' 'full of piety and humanity,' and 'ye shall also understand.' Over the centuries, there have been many interpretations of the *New Atlantis*. Here, we emphasize its discourses on Human Nature because STM finds this topic prominently in that work.[18]

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[18] This is the topic that is most prominent in *The New Atlantis*. The topic has no connection to the organization of science, the interpretation most often associated with that work (Sargent 1996).

The remaining science topics are all related to Bacon's writings on the philosophical study of nature and the physical universe. All names for these topics are self-evidently justifiable from both the highest probability and FREX words. We name these topics Botany, Pharmacology, Physics (Air & Sound), and Physics (Energy). A fuller discussion of the content of these topics would have little relevance to the substance of this paper.

4.7 Methodology

The final theme has three topics addressing methodology, Bacon's most renowned contribution to knowledge. The documents most highly associated with the first of these topics are heterogeneous. Several top documents are sections from the *Wisdom of the Ancients* and from *History Natural and Experimental of Life and Death* in which Bacon attempts to derive scientific lessons from the lives of biblical, mythological, Greek, and Roman characters. There is also a section of *The Advancement of Learning*, where Bacon interprets the contributions of historical figures. A disquisition on Queen Elizabeth attributes her success to a contested succession because 'Princes brought up in Regal houses, to hope of succession not uncertain, are often depraved with soft and licentious breeding, and become immoderate in their reign.'[19] Thus, Bacon uses historical and mythological stories to generate quasi-scientific insights, consistent with his broad philosophy that all experience should be used to advance natural philosophy. We name this topic Extracting Meaning.

The last two topics constitute two elements of the set of ideas that Bacon's later followers came to refer to as the 'Baconian program' (Mokyr 2005, 2010, 2016).[20] The key to understanding the first of these two, Probing for Facts, is that there are two words that are used with a high probability by this topic—'ask' and 'answer'— and that are highly specific to this topic, as indicated by the FREX words. This is consistent with the common thread that we find in the disparate collection of highly ranked documents. Several are sections of the *Apothegms*, a collection of isolated short stories that often describe one person asking and another answering. In the top documents, there are three charges made by Bacon as prosecutor. Bacon asks why a person is guilty and answers with evidence. There is also one case from Coke's reports, Sir Stephen Procter's Case, discussing the status of the law when judges are divided in how they answer the question on somebody's guilt. Thus, STM identifies a key aspect of Bacon's scientific method that encourages asking questions and finding answers wherever they can be found, an aspect of Bacon's thought highlighted by many scholars (see, e.g., Peltonen 1996a: 17; Mahlerbe 1996, Mokyr 2005: 289, 304).

The label of the final topic, Epistemology, follows immediately from its most highly associated words: 'philosophi,' 'knowledg,' 'method,' 'system,' 'logic,' 'inquiri,' 'discoveri,' 'experi,' 'axiom,' 'theori,' etc. The most prominent documents

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[19] In 'The Felicity Of Queen Elizabeth.'

[20] The naming of these two topics is the same as that in Grajzl and Murrell (2019), which focuses only on Bacon but uses the same corpus of Bacon's works as in this paper.

are sections from the *Novum Organum* and *The Advancement of Learning*, the foremost works cataloging Bacon's methodology. For example, the most highly associated document is a section of the latter where Bacon argues that '…the induction which the logicians speak of…whereby the principles of sciences may be pretended to be invented…is utterly vicious and incompetent…For he that shall attentively observe how the mind doth gather this excellent dew of knowledge…shall find that the mind of herself by nature doth manage and act an induction much better than they describe it. For to conclude upon an enumeration of particulars, without instance contradictory, is no conclusion, but a conjecture….'

4.8 Insights into early seventeenth-century legal–intellectual culture

The estimates from STM provide an integrated overview of the works of Bacon and Coke. This overview provides a picture of the intellectual relationship between the two authors that is different from current characterizations in the literature. The analysis places their works on an equal footing and produces a quantitative assessment. It generates novel insights into the contributions of Bacon and Coke to seventeenth-century ideas and culture.

Thirteen of the 25 topics are legal ones. Of the thirteen, only six would fit standard area-of-legal-application categories within modern classification schemes (Property Rights; Land Inheritance Law; Criminal Justice System; Constitutional Law; Jurisprudence; King, Law, & Nation).[21] Three legal topics are on legal scholarship (Understanding Law; Jurisprudence; Disambiguating Law), with two of these, Understanding Law and Disambiguating Law, hardly to be expected from the existing literature. Most importantly, four legal topics cross area divides in ways that are suggestive of a deep hidden structure to legal reasoning: Defendant Rights, Regulation of Exchange, Public & Private Authority, and Legal Jurisdiction. These topics are conceptual rather than substantive. For example, Defendant Rights ranges across many areas of the substantive application of law, capturing general conceptual ideas concerning which defenses are admissible or desirable, and when. Similarly, the ideas embodied in Legal Jurisdiction are used to discuss disputes between courts, between nations, between church and state, between the Crown and the law, and between varieties of legal officials. In early seventeenth-century English culture, the ideas in the common law structured debates about conflicts of all kinds.

Thus, our STM estimates show commonalities between different subjects that do not appear in standard treatments. Often, the estimates do more than simply reflect the ostensible focus of a work—for example, crime or contract: they reveal a commonality between writings that span different areas of the application of law. Coke is the primary user of these topics, but Bacon also uses them. This suggests a commonality in their deployment of legal reasoning. It was always a dream of Bacon, never accomplished, to systematize the common law in a way that would reveal its

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[21] For example, that used for the *Journal of Economic Literature* (https://www.aeaweb.org/jel/guide/jel.php) or by LexisNexis (https://www.lexisnexis.com/LegalNewsRoom/lexis-hub/b/legaltoolbox/posts/area-of-law-research).

deeper structures and logic. In the end, Coke's unwieldy and rambling *Institutes* and *Reports* were the closest anybody in the seventeenth century came to explicitly accomplishing this goal, as Bacon grudgingly acknowledged (Cromartie 1999: 86). Nonetheless, our estimates suggest a sophisticated structure within seventeenth-century common-law reasoning, but one that was implicit rather than explicit, and perhaps not even understood clearly by the lawyers themselves.

Figure 1 illustrates the relative importance of the various topics in the whole corpus. We note that the topics that capture more general concepts, methodology, or modes of understanding, tend to rank above average in importance, contrasting with the topics that center on domains of application. This suggests that these more general topics are used across a wide range of documents, and therefore a wide range of subject areas.

Finally, it is important to identify topics that could have been identified by STM, but were, in fact, not. This is part of the process of defining the set of ideas that exists in a specific milieu: in delineating the features of a distinct culture, it is necessary to identify what views and ideas were absent from the core components of that culture. Here we simply focus on those ideas that have been prominently attributed to Bacon and Coke in the existing literature but which we do not find in the STM topics, meaning that they were not emphasized by the authors. For example, Coke has sometimes been characterized as a proponent of laissez-faire and an ally of commercial interests, most famously by Heckscher (1935) and Hill (1965). Our 25-topic STM identifies no topics that could be associated with these ideas. As in Grajzl and Murrell (2019), there is also no topic that could be interpreted as capturing utilitarianism nor one that focuses on the centralized organization of science. These are ideas that were adopted by eighteenth-century Baconians and often attributed to Bacon himself. However, our estimates do not provide evidence in favor of this attribution: these ideas are not emphasized in the corpus.[22] As we demonstrate in Appendix D, these findings are fully robust to estimating a 100-topic STM that offers an overview of the corpus at a much higher level of granularity.

5 Exploring the connections between the cultural topics

In this section, we use STM to assess the relationships between the estimated topics, harnessing the power of machine learning to identify commonalities among the cultural ideas featured in different topics. These commonalities would not be readily apparent to a human reader in the sense that they reflect minutely detailed patterns in word usage both within and across documents, together with variations in such patterns that are associated with the values of metavariables. In particular, as we

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[22] The literature on Bacon's influence most often emphasizes four contributions. As in Grajzl and Murrell (2019), STM finds two of these, the inductive logic of interpreting the world (Epistemology) and the focus on cataloging the world (Probing for Facts). See, for example, Peltonen (1996), Rossi 1996), and Malherbe (1996). STM does not find any emphasis on the utilitarian value of produced knowledge or on centralized organizational arrangements for scientific investigation. See, for example, Rossi (1968), Gaukroger (2001), Mokyr (2005, 2010), Sargent (1996), and Harkness (2007).

For each topic, the figure displays the assigned names and the top fifteen FREX words. The size of the bars to the left of each topic is proportional to the probability that a random word drawn from the whole corpus has been generated by that particular topic

Fig. 1 Expected values for topic proportions in the Bacon and Coke corpus

demonstrate below, an examination of topic connectedness illuminates an important facet of Religion, Law, & Truth: it is a methodological topic drawing on examples from religion and law, as opposed to a topic about either religion or law per se.

We first examine document-level correlations between topics. Documents are mixtures of topics. Co-occurrence of two topics at the document level is evidence of complementarity in the use of topics. It shows that the two topics aid each other in expressing a specific set of ideas, indicating a shared conceptual foundation. We then examine vocabulary overlap between topics. Doing so allows us to assess the degree to which topics share a common semantic foundation.

Figure 2 provides a visualization of all positive topic correlations. The thickness of a link indicates the strength of the corresponding pairwise correlation. Among the featured correlations, the average correlation coefficient (ρ) equals 0.079[23] (the complete set of correlation coefficients between topic pairs is summarized in Table E1 in Appendix E). The positive topic correlations featured in Fig. 2 can be visualized as comprising four elements: the nexus of legal topics (top-left); the nexus featuring a mixture of scientific and social-scientific topics predominantly used by Bacon (to the right); a three-topic nexus consisting of two core methodological topics, Understanding Law and Epistemology, and an associated one, Religion, Law, & Truth (in the center); and the completely disconnected Dynastic Politics. In the following, we examine each of the three connected parts of the nexus.

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[23] The data-generating model implies that if all data were random, the correlation between topics would be -0.0417. Figure 2 captures the 11.3% of highest-valued correlations.
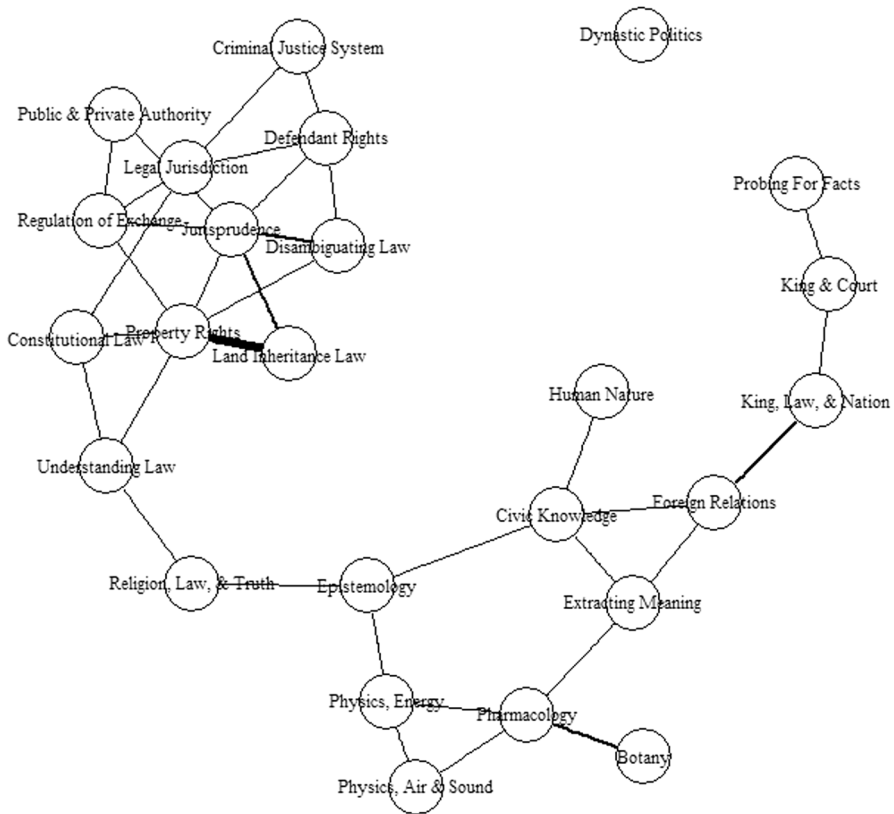
The relative thickness of links reflects the magnitude of (positive) correlations between respective topic pairs

Fig. 2 Positive topic correlations

5.1 A common law culture

The legal nexus comprises all legal topics featured in the corpus, with the exception of King, Law, & Nation. Most topics in the legal nexus are used by both Bacon and Coke. In particular, at the heart of the legal nexus is Jurisprudence, which is used equally by the two authors. Jurisprudence is correlated with six other topics, including Disambiguating Law ($\rho = 0.225$), also a more theoretical legal topic used equally by both. We view this as direct evidence that Bacon and Coke shared much legal theorizing.

Several other patterns stand out within the legal nexus. The cluster of correlations among Defendant Rights, Criminal Justice System, and Legal Jurisdiction illuminates the co-occurrence of ideas that form the foundation of modern-day criminal law and justice ($\rho = 0.105$ between Defendant Rights and Criminal Justice System; $\rho = 0.103$ between Criminal Justice System and Legal Jurisdiction; $\rho = 0.063$ between Defendant Rights and Legal Jurisdiction). Property Rights, a fundamental

private law topic, is strongly correlated with Land Inheritance Law ($\rho = 0.458$), as one would expect, but also with both Disambiguating Law ($\rho = 0.167$) and Jurisprudence ($\rho = 0.111$). The latter pattern is consistent with the old common-law theme that the legal rights of Englishmen were viewed as inherited property, and indeed the connection between Property Rights and Constitutional Law ($\rho = 0.078$) shows how the two were intertwined. Public & Private Authority and Regulation of Exchange are especially likely to co-occur ($\rho = 0.177$). They are featured prominently in Coke's work. This is evidence of an early culture of regulation, while counter to the view that Coke was an advocate of laissez-faire.[24] Finally, the correlation among Constitutional Law, Property Rights, and the methodological Understanding Law foreshadows ideas and scholarship on the rule of law ($\rho = 0.077$ between Constitutional Law and Property Rights; $\rho = 0.058$ between Property Rights and Understanding Law; $\rho = 0.117$ between Constitutional Law and Understanding Law).

5.2 A culture of the methodology for expanding knowledge

The legal nexus is connected with the scientific and social-scientific nexus through Understanding Law, which is dominated by Coke, via Religion, Law, & Truth, used by both authors, and Bacon's Epistemology[25] ($\rho = 0.161$ between Understanding Law and Religion, Law, & Truth; $\rho = 0.058$ between Religion, Law, & Truth and Epistemology). The STM correlations indicate that Religion, Law, & Truth has many characteristics of—and in fact may be thought of as—a methodological topic.

Given the centrality of the methodological nexus, we investigate the connectedness between Religion, Law, & Truth, Epistemology, and Understanding Law by analyzing overlaps in vocabulary use, which indicate common semantic foundations. Figures 3, 4 and 5 present a series of plots featuring the top 80 FREX words for each chosen topic pair. In each of the plots, the size of any displayed word is proportional to the word's use within the featured topic pair. The horizontal position of a word measures the difference in the probabilities that associate a word with each topic, normalized by the maximum difference that occurs in the set of 80 words (Roberts et al. 2016b, fn. 20). The horizontal position of each word thus conveys how common a word is in one topic versus the other topic.[26] Words located close to the vertical dashed line are ones shared equally by the two topics.

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[24] See Heckscher (1935) and Hill (1965) for such a characterization of Coke. In contrast, Malament (1967) rejects the characterization of Coke as proponent of laissez-faire.

[25] Grajzl and Murrell (2019) examine the genesis of Bacon's scientific methodology and provide quantitative evidence of the common-law origins of Bacon's epistemological thought. The results in Fig. 2 are consistent with that evidence in that use of Epistemology co-occurs with the use of Religion, Law, & Truth. In Fig. 2, Epistemology is also connected to Civic Knowledge, a finding suggestive of the influence of Renaissance humanism on Bacon's epistemological ideas (see Gaukroger 2001). Analysis of overlapping vocabulary between topic pairs reveals that the connection between Epistemology and Religion, Law, & Truth is stronger than the connection between Epistemology and Civic Knowledge. This suggests that any influence of Bacon's background in Renaissance humanism on his epistemological reasoning was weaker than the influence of his immersion in common law. Detailed evidence supporting this point is available upon request from the authors.

[26] In contrast, the vertical position of a word is random and carries no substantive interpretation.

The shared semantic foundations of Religion, Law, & Truth, Epistemology, and Understanding Law are clearly identifiable. While Epistemology focuses on 'natur' and Religion, Law, & Truth on 'church' and 'god,' both use 'reason,' 'true,' 'cause,' 'understand' and words employed in logical reasoning such as 'yet,' 'upon,' 'matter' and 'without' (Fig. 3). Similarly, while Understanding Law is concerned with 'law' and 'king,' it shares with Religion, Law, & Truth 'learn,' 'know,' 'reason,' 'judgment,' 'true,' together with 'yet,' 'upon,' and 'without' (Fig. 4). In the same vein, Epistemology and Understanding Law share the emphasis on 'learn,' 'understand,' 'true,' 'reason,' 'caus,' 'know,' 'observ,' and 'find,' as well as the logical words 'upon,' 'see,' 'therefore,' 'yet,' and 'matter' (Fig. 5). Consistent with the evidence from topic correlations, Epistemology and Understanding Law capture two seemingly disparate, but methodologically congruent, approaches to understanding the world, while the applied methodology of Religion, Law, & Truth links them. The set of ideas in these three topics captures elements of a culture reflecting the methodology used in expanding knowledge.

5.3 A culture of inquiry, scientific and social scientific

The scientific and social-scientific nexus features a collage of topics on natural science, methodology, politics, and even psychology, all strongly dominated by Bacon. Coke's work hardly figures here. This is easily explained: Coke writings concentrate on law. Given that our primary interest is in identifying shared elements of the ideas of Bacon and Coke, we comment on this nexus only very briefly.

Notably, a cluster of natural science topics is correlated with two methodological topics, Epistemology and Extracting Meaning. Extracting Meaning, a topic using old texts to pursue new inquiries, co-occurs with a political theme (Foreign Relations; $\rho = 0.063$) and with Civic Knowledge ($\rho = 0.116$), a topic highlighting Bacon's background in renaissance humanism with its spirit of inquiry into the practice of government. Also included in this cluster is Probing for Facts, a broad methodological topic emphasizing the need to ask questions to generate facts about the world. In sum, the connections between methodological topics and practical scientific investigation are indicative of a culture stressing the importance of inquiring into how the world works and thereby building reliable knowledge. This is a culture of empirical inquiry, in great contrast to the deductive approach in interpreting existing facts that was characteristic of the prevailing Aristotelian paradigm.

6 Identifying differences and similarities between Bacon and Coke

The previous section has shown that a machine learning analysis of the Bacon–Coke corpus provides evidence of considerable consistency between the ideas of these two intellectual giants. But this insight leads to something of a paradox because the existing literature that utilizes conventional text analysis has invariably emphasized differences. In this section, we leverage STM's use of metavariables to explore the differences and similarities between the topical emphases of the two intellectuals.

Fig. 3 Vocabulary use across topic pairs: Epistemology versus Religion, Law, & Truth

Fig. 4 Vocabulary use across topic pairs: Understanding Law versus Religion, Law, & Truth

Fig. 5 Vocabulary use across topic pairs: Epistemology versus Understanding Law

We show that although Bacon and Coke certainly differ in their emphases on specific ideas, there are also important similarities between them. These similarities appear especially when estimates of topic prevalence are conditioned on the intended audience and, above all, on the time at which the works were produced.

A caveat is in order before proceeding with the analysis. Topic modeling, with its conceptualization of text as a bag of words and reliance on a macroscopic lens to view the corpus, is a blunt tool for uncovering fine semantic similarities and distinctions between the ideas of different authors. For example, it could be that two authors reach opposite conclusions about a subject while using very similar words so that STM finds no difference in topic prevalences.[27] Nevertheless, given the existing literature's predominant narrative of the conflicts between the ideas of Bacon and Coke, quantitative evidence of similarities in the authors' emphases on specific

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[27] There is an important lacuna in the methodological literature on STM that is relevant at this point. There is no agreement on whether divergent opinions on a given subject will inevitably result in differences across authors in the prevalences of the topics relevant to that subject, or whether authors could have similar topic prevalences and yet still feature substantively divergent opinions. The former seems to be the dominant view in practical applications of STM. Examples can be found in Tingley (2017), Lynam (2016), Farrell (2015), Reich et al. (2015), and Tvinnereim and Fløttum (2015). If we took this point of view, then the results presented in the ensuing section would imply that Bacon and Coke had substantively similar views on many aspects of law, for example. But given the methodological lacuna, we do not jump to this stronger conclusion.

topics—as well as in the pattern of the evolution of those emphases—would alone constitute an important finding.

At the same time, STM offers scope for a comparatively more nuanced analysis of differences and similarities between the ideas of Bacon and Coke than some of the alternative approaches for comparing textual corpora, such as the use of Kullback–Leibler/Jensen–Shannon divergence measures or cosine similarity (see, e.g., Gallagher et al. 2018; Lu et al. 2018; Gomaa and Fahmy 2013). Much like STM, these alternative approaches rely on a bag-of-words representation of text. However, unlike STM, they infer differences and similarities between texts based on word frequencies alone, without identifying coherent topics, without leveraging the correlation of words across documents, and without allowing for the possibility of the influence of metadata covariates on the prevalence of specific ideas.

6.1 Unconditional analysis

Figure 6 shows how the proportions of topic use in the documents written by Coke differ from the same proportions for Bacon. For example, the proportion of Understanding Law in Coke documents is nearly 0.1 higher than in Bacon documents and the 95% confidence interval for the estimated difference in proportions lies between 0.04 and 0.14.

In some respects, Fig. 6 shows how the dominant view in the literature might have arisen: overall there are considerable differences in topical emphases between Bacon and Coke. For most topics, there is no overlap between the confidence intervals and the zero line, the line indicating that both use a topic equally. When examining the whole corpus the two authors look quite different—one is a scientist-methodologist and the other is the lawyer. Using Fig. 6, the only way in which the dominant view could be subject to some scrutiny would come from a focus on Jurisprudence, Disambiguating Law, and Religion, Law, & Truth: the differences between Bacon and Coke are not statistically significant at the 95% level. But this is only three of 25 topics.

In ascertaining similarities or differences between the two authors' emphases, Fig. 6 has a problem: it reflects the whole corpus. We do know that Bacon and Coke had very different careers, both over time and in the different audiences they would need to address. Perhaps the unconditional differences highlighted in Fig. 6 simply reflect the broad outlines of their careers. For a more precise comparison, it is necessary to compare the two when they are writing for similar audiences or at a particular point in time.

6.2 Conditioning on target audience and communication form eliminates some differences but amplifies others

There exist only a limited number of cells of the metadata variables where both Bacon and Coke contribute a non-trivial number of documents to our corpus
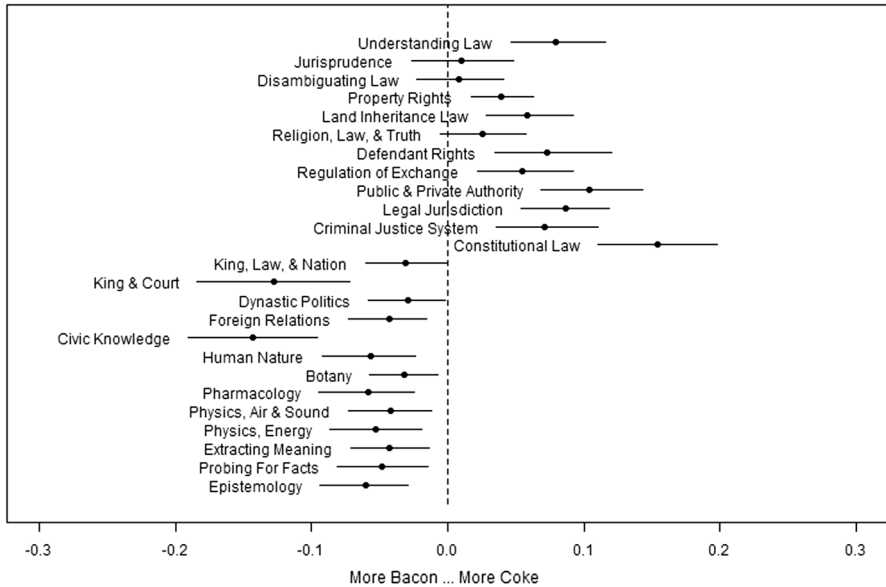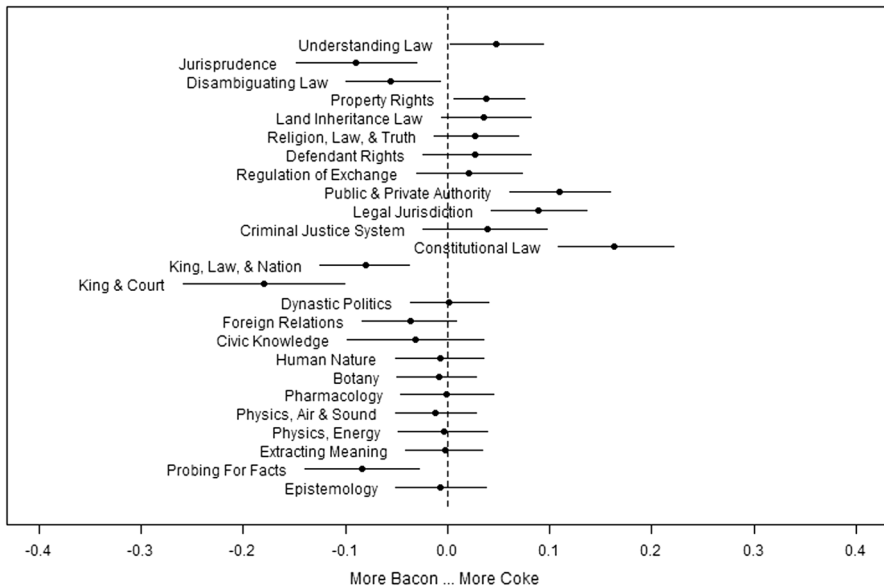
Fig. 6 Use of the 25 topics: Bacon versus Coke

(Table 2). These situations especially involve the targeting of lawyers, and to a lesser extent also methodologists and politicians. Also, the two authors both contributed speeches.[28] In interpreting the results produced by conditioning on the values of metavariables, it is important to keep in mind that it would be perfectly natural for both Bacon and Coke to ignore certain topics when addressing specific audiences (e.g., Pharmacology or Botany to lawyers or politicians). Thus, the absence of a statistically significant difference in the authors' emphases on such topics does not imply anything about similarities between the authors' topical uses; it would simply reflect a general lack of relevance of the specific topic in a given situation. In the ensuing discussion we therefore purposefully ignore such topics.

We first investigate the consequences of conditioning on documents addressed to lawyers (Fig. 7). Note that, in this case, Coke contributes more documents than Bacon and the total number of considered documents (205) is adequately large. Moreover, relative to unconditional analysis, conditioning on lawyers somewhat improves the balance in the documents contributed by the authors (Table 2). Conditioning on lawyers, in contrast to the unconditional analysis (Fig. 6), shows that it is Bacon, 'the lawyer without law'—not Coke, 'the greatest oracle of our municipal jurisprudence'—who places more emphasis on Jurisprudence and Disambiguating Law. Bacon and Coke also differ notably in their emphases on affairs conducted at

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[28] The only other communication form that both Bacon and Coke used extensively was essays, but this category includes such a heterogeneous collection of documents that conditioning on essays does not yield any new insights beyond reducing some of the unconditional differences by a small amount.

Fig. 7 Use of the 25 topics: Bacon versus Coke when addressing lawyers

the nation's highest level. Coke, an important constitutional actor, emphasizes Constitutional Law whereas Bacon, deeply embedded in court politics, emphasizes the matters that directly touched on the monarch's current decisions and place in the country (King & Court; King, Law, & Nation). This is evidence that the two authors thought very differently about the place of the monarch in England's constitutional politics.[29] However, in most areas of the concrete application of the law (Land Inheritance Law; Defendant Rights; Regulation of Exchange; Criminal Justice System), conditioning on lawyers eliminates statistically significant differences in the authors' emphases on topics that both used when addressing legal audiences. That is, with respect to their emphases on a range of substantive areas of law, Bacon and Coke were certainly not as dissimilar as one might have expected them to be based on the depictions in the existing literature utilizing conventional textual analysis.

Conditioning on documents addressed to politicians and methodologists, as well as conditioning on speeches, decreases the number of eligible documents and, in the case of conditioning on politicians and methodologists, increases the imbalance in the proportion of documents attributable to each of the authors. This tends to increase the confidence intervals for the estimates of differences in the authors' topical emphases. Nevertheless, conditioning on methodologists (Fig. 8) amplifies the divergence between the authors' uses of their own methods for pursuit of

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[29] This point harks back to the second, methodological, paragraph of Sect. 6. In an area in which it is beyond dispute that Bacon and Coke had profound differences, these differences do clearly result in STM estimating two separate topics in the same subject area (King, Law, & Nation and Constitutional Law).
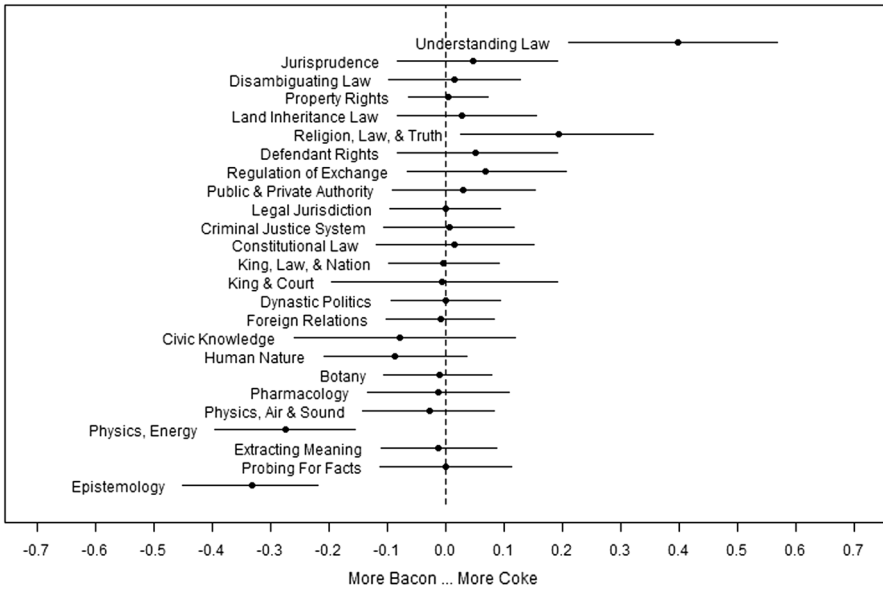
Fig. 8 Use of the 25 topics: Bacon versus Coke when addressing methodologists
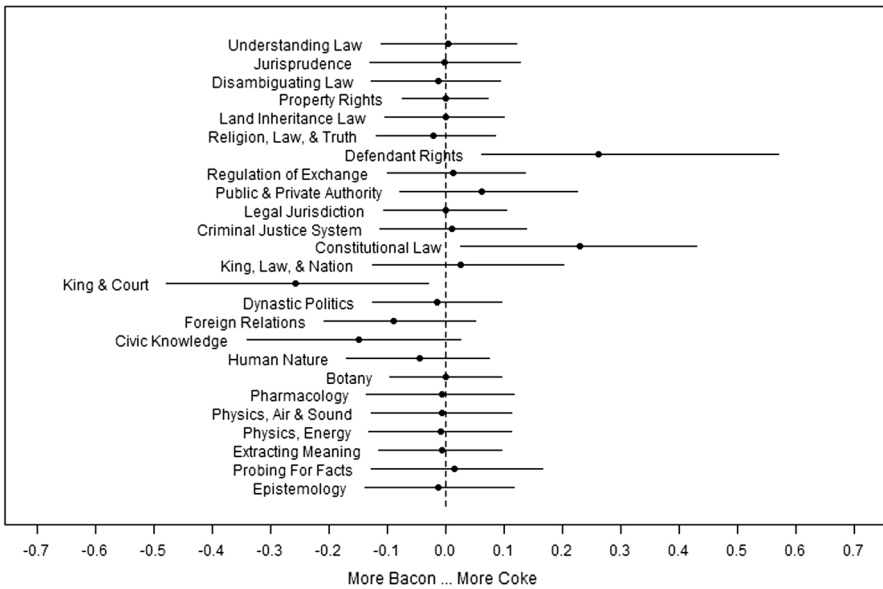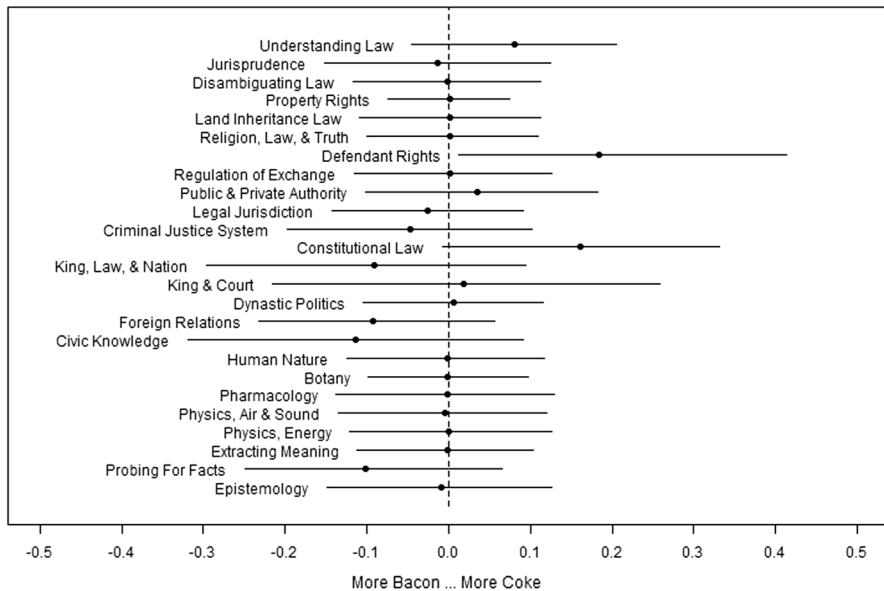

Fig. 9 Use of the 25 topics: Bacon versus Coke when addressing politicians

Fig. 10 Use of the 25 topics: Bacon versus Coke when making speeches

knowledge: Epistemology for Bacon and Understanding Law for Coke. In this context, Religion, Law, & Truth, which is used by both authors, is more important for Coke than Bacon. Similarly, conditioning on documents directed at politicians (Fig. 9) preserves the unconditional differences between the authors with respect to their emphasis on topics such as Defendant Rights, Constitutional Law, and King & Court. These differences perhaps reflect the kind of politicians being addressed: Coke addresses Parliament, while Bacon produces essays on strategy in interpersonal relations or private letters to the monarch or courtiers.

When conditioning on speeches (Fig. 10), we see that Coke in comparison with Bacon emphasized Defendant Rights. It is possible that this finding points to the authors' differential willingness to engage in strategic communication of their ideas at a time when political disfavor could be very costly. Coke, who 'stubbornly fought to limit the king's prerogative powers' (Berman 1994: 1674) was willing to publicly articulate his convictions about the importance of defendant rights. Bacon, in contrast, carefully distinguished between his public and private utterances, as can be seen by contrasting Figs. 6 and 10. Elements of his writings might have been public lies, covering private truths (Kuran 1995).

In sum, conditioning on targeted audience and communication form eliminates some estimated differences in the topical emphases of Bacon and Coke, but amplifies others. The resulting analysis, however, does not incorporate the potentially important role of time: after all, the intellectual and professional pursuits of the two authors followed different timelines. A quantitative examination of their changing topical emphases over time thereby offers a unique analytical perspective for analysis of the conception and the evolution of thought of the two lawyer-intellectuals. As

we illustrate below, it is precisely this exercise that allows us to uncover profound similarities between Bacon and Coke.

6.3 Conditioning on time reveals a fundamental similarity between Bacon and Coke

Figures 11, 12, 13 have together 25 elements, each depicting the change over time in the use of one of the topics by both authors. Bacon's timelines are represented by solid lines while Coke's are dashed. There are three lines for each, the estimated mean topic proportion over time and the 95% confidence bounds for the estimated mean (where only two lines appear for an author, the lower 95% confidence bound lies completely below zero). With the exception of the earliest period, Bacon's documents are more abundant than Coke's, and thus the confidence intervals around the estimated mean topic proportions tend to be smaller for Bacon than for Coke. Yet this imbalance in featured documents should not affect the conclusions we draw in this subsection, as our interest here is in ascertaining the broad patterns in the evolution of the two authors' changes in topical emphases over their respective lifetimes. We do not focus on assessing differences in the emphases of the two authors on specific topics at any particular point in time.

The young Bacon is the quintessential common lawyer, using standard topics when applying the law concretely. He contributes in such areas as Land Inheritance Law, Defendant Rights, the Criminal Justice System, and the Regulation of Exchange. The theoretical cast to his writings begins early: Jurisprudence and Disambiguating Law are used heavily even at the beginning of his career. Indeed, Bacon's emphasis on these two topics fades only slowly during his life, whereas emphases on concrete applications of law decline earlier. These applications of law are replaced by scientific topics, beginning in mid-career and rising steeply in importance thereafter.

The timelines provide insight into the sources of Bacon's most celebrated intellectual contribution, his work on the methodology of science. From the very beginning, Bacon was using his Epistemology and his use of this topic increased throughout his life. Thus, it was not the turn to science that spurred the development of Epistemology: it was already present from the very beginning when Bacon focused on law. This endorses the conclusion, already mooted in Sect. 5, that Bacon's Epistemology was a product of his education in the common law and his early experiences at the center of the legal profession. This conclusion is buttressed by the observation that Bacon used the proto-methodological topic, Religion, Law, & Truth, in his earliest contributions and that this topic stayed with him throughout his life, even as his writings focused increasingly on science and social science.

Bacon's other great methodological contribution, Probing for Facts, shows a very different trajectory from Epistemology. It is not present in the young Bacon, when he was focused on legal subjects. But its use begins before the turn to science, indicating that there is no evidence that Probing for Facts was a product of Bacon's later-life concern with science. Probing for Facts seems to be more sui generis Bacon than is Epistemology.
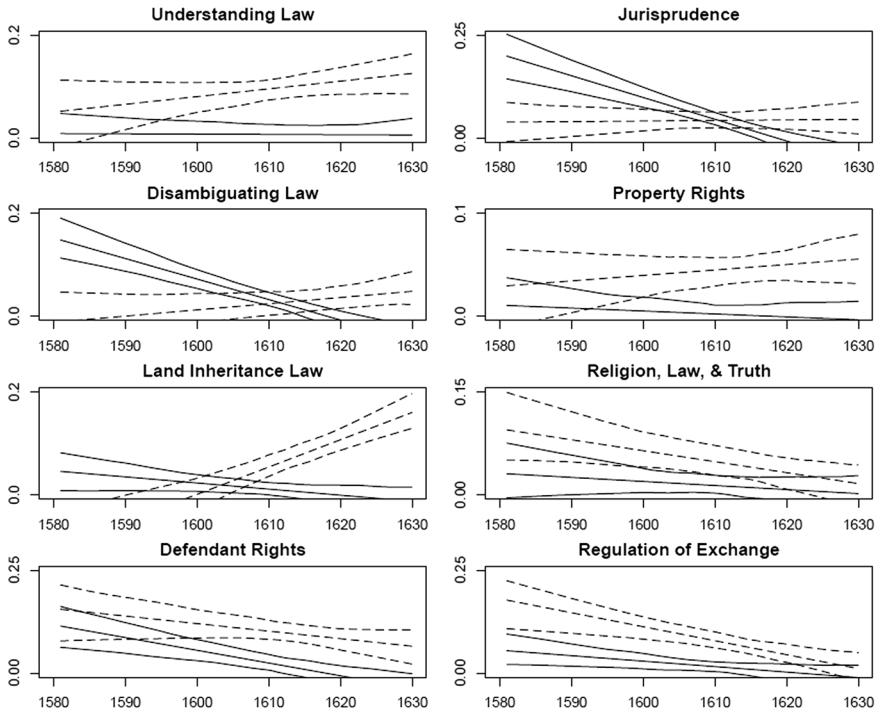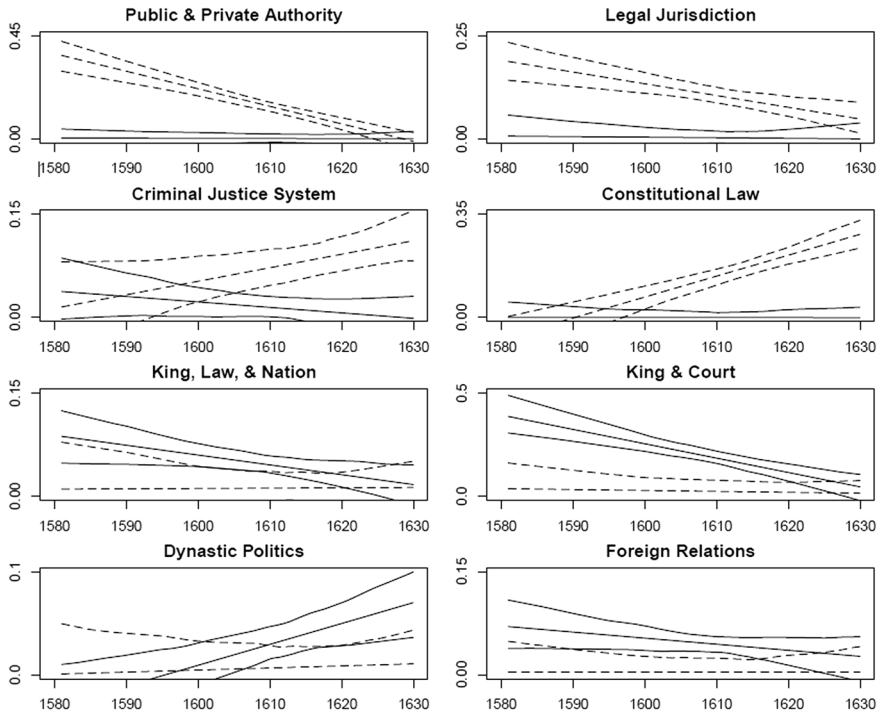
Estimated mean values for topic usage and 95% confidence intervals. Solid lines are for Bacon, dashed lines for Coke

Fig. 11 Variations over time in the use of the 25 topics by Bacon and Coke

It is easy to see from the topics emphasized in Coke's early writings how he could be cast as a typical medieval legal thinker. His most important topics are standard concrete applications of law—Defendant Rights, Regulation of Exchange, Legal Jurisdiction, and Public & Private Authority. There is no theoretical cast to his writings, in contrast to Bacon. For the young Coke, Understanding Law is a much less important topic than it would later become, Disambiguating Law does not appear, and Jurisprudence is overshadowed by topics reflecting applications of law. But there is one exception to this characterization, Religion, Law, & Truth, which is important in the first years of Coke's writings.

As the years pass, Coke moves to more general, more conceptual modes of deliberation. He places more emphasis on methodology (Understanding Law), on more theoretical aspects of law (Disambiguating Law), and on law at the highest level (Property Rights and Constitutional Law). One conjecture that might explain this broadening is Coke's change from being a servant of the monarch to a Chief Judge who guarded his independence jealously. But this reasoning is inconsistent with the observation that Coke's use of Legal Jurisdiction and Public & Private Authority declines greatly over time: these would be exactly the legal themes emphasized by a Chief Judge who was highly protective of his territory.

Estimated mean values for topic usage and 95% confidence intervals. Solid lines are for Bacon, dashed lines for Coke
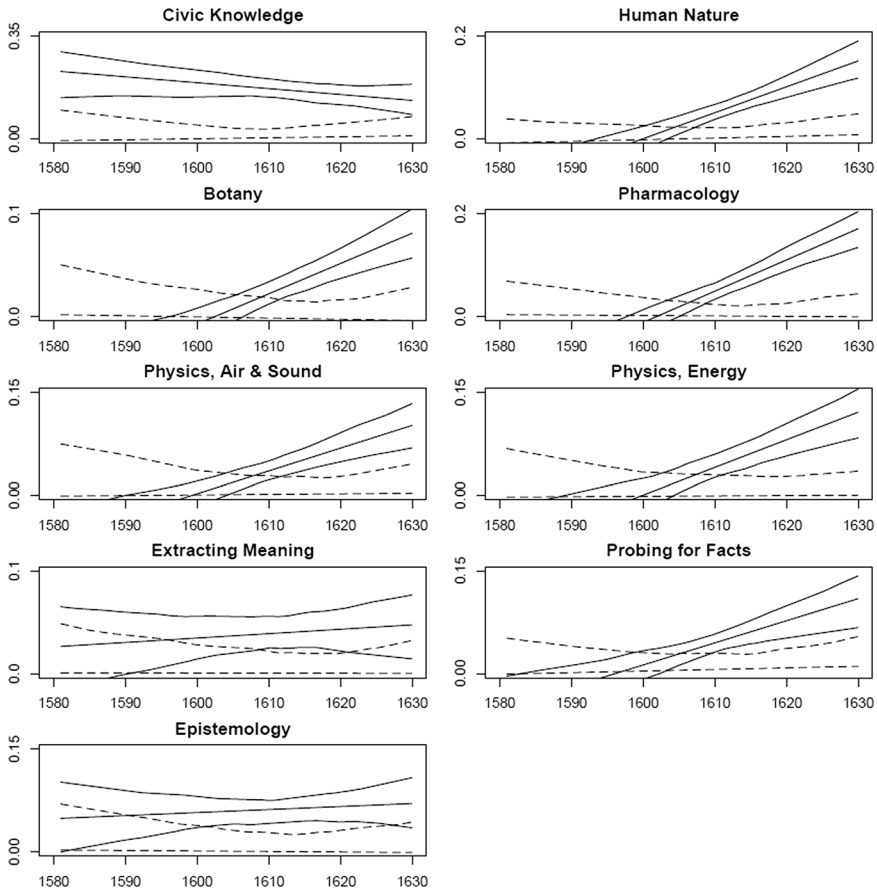
Fig. 12 Variations over time in the use of the 25 topics by Bacon and Coke

A hypothesis that is more consistent with the topic timelines is that Coke was gradually developing his own broader theoretical approach to legal reasoning. In terms of the language of others, he was moving away from having 'no theory at all' (Berman 1994) while simply dealing in an unsystematic set of rules (Siegel 1981) to having a systematic general perspective on legal reasoning.

Conditioning on time, therefore, reveals a fundamental congruity between the ideas of Bacon and Coke. At the beginning of their careers, they could each be characterized as traditional lawyers in the common-law mold. They worked on similar topics in apparently complementary ways. In the earlier years, Bacon had a more theoretical bent to his writings. But the later Coke did employ a coherent methodological approach, one that had many similarities with Bacon's better-known methodology, as Sect. 5 has already shown.

The evolution of the ideas of Bacon and Coke exhibits a common thread. Bacon moved from an emphasis on a conceptual understanding of common-law reasoning to a general scientific methodology. Coke began by immersing himself in the details of the common law but then moved on to develop a broader legal theorizing. Both moved from the particular to the general, but eventually in disparate fields of inquiry. Therefore, one cannot say, as the literature often does, that Bacon was modern and Coke medieval. They were both grappling with the crucially important issue

Estimated mean values for topic usage and 95% confidence intervals. Solid lines are for Bacon, dashed lines for Coke

Fig. 13 Variations over time in the use of the 25 topics by Bacon and Coke

of how to derive truthful statements from a set of apparently disparate facts. Both used the inductive approach that had developed for centuries as common lawyers wrestled with generalizing from particulars. This was the intellectual culture that these two intellectual giants both imbibed and advanced.

7 Conclusion

The period spanning the late sixteenth and early seventeenth centuries was pivotal for England. At the dawn of an era of fundamental institutional changes and technological advances, elements of a distinct intellectual culture were taking shape, a culture that would leave a lasting imprint on the modern world. We have estimated the features of one aspect of this emerging culture by analyzing the

works of Francis Bacon and Edward Coke, two lawyer-scholars who did much to contribute to the new intellectual environment. We thereby offer the first quantitative analysis of the legal–intellectual ideas that immediately preceded, and provided key input into, the subsequent, eighteenth-century culture that is believed to have spurred pioneering inventive activity and sustained technological progress (Mokyr 2016). Our insights into early-seventeenth-century English culture therefore provide a key step in understanding the cultural origins of England's rise, a topic that has stimulated a voluminous body of research on comparative economic development, and in economic history in general.

Among the many detailed cultural and historical observations that we make, the following three substantive conclusions deserve particular emphasis. First, common-law thinking, as exemplified in the work of both Bacon and Coke, had by the early seventeenth century already developed a deep, theoretical structure. Applications cut across conventional legal subjects found in standard legal-classification schemes. That is, early-seventeenth-century English common-law thought was not simply an atheoretical collection of cases and facts, as has been the standard characterization.

Second, the interconnected nexuses of ideas in the corpus suggest a commitment to the systematic derivation of truthful statements from facts, combined with an emphasis on practical inquiry as a means of understanding the broader world. Looking forward, these components of early-seventeenth-century English legal–intellectual culture provided an important input into the much broader culture, one that would eventually facilitate lasting economic progress. Looking backward, these components of culture are intimately linked to the use of common law-style reasoning, which had been in development for many centuries.

Third, while Bacon and Coke differed in their emphasis on specific subjects, their works evidence a methodological commonality that has not been discussed in the literature to date. Bacon's much celebrated epistemology is closely related to Coke's supposedly absent theoretical approach to understanding the law. Both derive their approach to understanding the world using the inductive reasoning inherent in common-law thought. Their shared methodology emphasizes practical inquiry and the building of reliable knowledge. The presence of this methodology in the works of both authors suggests that it is a central element of seventeenth-century English legal–intellectual culture.

Finally, we highlight a methodological point. Our analysis illustrates how machine learning, and in particular structural topic modeling applied to original texts, can be productively utilized to investigate the features of a culture. Given the recent substantial interest among economists in the study of culture, our approach suggests a novel quantitative approach to ascertaining the core characteristics of a culture prevailing in a specific time and place.

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