Professional Knowledge-Building Institutions and the Historical Emergence of Accounting Norms*

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ABSTRACT

Accounting norms preceded U.S. Generally Accepted Accounting Principles (GAAP), but little is known about how and why these norms emerged. We hypothesize that private-sector institutions aimed at building an accounting knowledge base fostered accounting norms before formal standard-setters were appointed in the 1930s. We identify specific U.S. institutions that helped shape a consensus on consolidated financial statements and other accounting issues. We use 'history-friendly' agent-based models to simulate how increased professional communication and institutional memory helped the emergence of norms. We find that widespread sharing of individual experiences stimulates professional convergence on more effective solutions as suggested by Canning (1929). While our focus is historical, most of the institutions we investigate continue to operate today. Our analysis suggests that powerful evolutionary forces likely shape modern accounting practice long before standard setters issue rules on any given problem.

Keywords: knowledge sharing, accounting profession, transactive memory, explicit knowledge, social networks.

JEL Descriptors: C630, D020, D830, L840, M400, N210, N220, O330.

INTRODUCTON

Norms reflect "customs," "habits," and "conventions" that define expected behavior and lead to behavioral conformity (Sumner 1906; Lewis 1969; Coleman 1990; Hechter and Opp 2001). Today's U.S. Generally Accepted Accounting Principles (GAAP) descends from accounting norms that grew out of 19th century practice and legal cases (Littleton 1933; Gilman 1939; May 1946; Zeff 1972).[1] We define an accounting norm as a behavioral regularity that sets customary expectations of accounting choice behavior for most professionals. Accounting norms evolve by "small, almost imperceptible steps, by processes that are neither observable nor well understood" (Sunder 2005, 374). Our research question is: how did private-sector knowledge-building institutions contribute to the emergence of accounting norms before the first U.S. accounting regulators were appointed in the 1930s?

A profession is an occupation that fulfills a public-service mission by cultivating, using, and protecting a body of valuable expert knowledge (Abbott 1988, Freidson 2001). The professional knowledge base is a form of social capital that the profession develops and sustains (Coleman 1988). A professional can learn from her own experiences and those of others captured in the profession's collective memory (Halbwachs 1950/1992; Wegner 1986). By the early 20th century, the U.S. accounting profession had built a knowledge base using several private-sector institutions. These institutions collectively enabled knowledge *acquisition* by individuals, knowledge *dissemination* through a growing network of professionals, and knowledge *retention* for use by current and future accountants (Argote 1999). Over time, such

[1] The central role of the law in guiding the evolution of accounting is evident in early accounting textbooks and handbooks. For example, the first chapter in the first edition of *The Accountant's Handbook* (Saliers 1923) was entirely on business law. Ball (2009) highlights the importance of court cases in guiding auditors' behavior today.

specialized knowledge became shared more widely and was less tied to individual accounting experts.

Our main hypothesis is that the private-sector institutions that promoted the acquisition, dissemination, and retention of professional accounting knowledge led to greater conformity in firms' accounting practices. We present evidence consistent with this hypothesis using a 'history-friendly' agent-based model (Malerba et al. 1999), which uses historical data to calibrate model parameters. Our simulations of several historical stages in the development of the U.S. accounting profession demonstrate how knowledge-building institutions can facilitate behavioral conformity around better solutions to problems than a random search would yield.

Prior historical research traces the emergence and growth of early knowledge-building institutions within the U.S. accounting profession (Edwards 1955; Carey 1969; Moonitz 1970; Miranti 1986; Previts and Merino 1998). These institutions include professional education and certification, professional journals such as *The Journal of Accountancy*, professional meetings to discuss current problems, and professional libraries. These institutions helped shape actual accounting practices long before statutory standard-setting bodies were created. One prominent example is the spontaneous emergence of consolidated financial reporting from accounting practice shortly after 1900 (Kracke 1938).

While historical analysis can identify the institutions that likely promoted professional knowledge development and document a temporal association between those institutions and select features of accounting practice, we lack sufficient historical data to establish a causal relation between professional knowledge development and the emergence of accounting norms. Because of this limitation, we use a simulation model to explore the relation between knowledge generation and behavioral homogeneity among a group of agents who solve a common problem while communicating within a social network. We calibrate agents' knowledge transfer and retention using data on U.S. accounting institutions during 1850-1930. This technique lets us collect data on interactions not directly observable in historical data while experimentally "controlling" the environment and manipulating variables of interest. Thus, we can study counterfactual historical paths that could have but did not occur rather than empirically studying only the historical processes and outcomes that occurred (Bastiat 1850/2007, 1-48; Hayek 1973, 15-17; Smith 2003, 471). In addition, such 'history-friendly' calibration models let us check verbal intuition in historical analyses and compare the relative importance of various mechanisms in explaining important outcomes (Malerba et al., 1999).

The agent-based model focuses on a problem (represented by a grid with alternative paths from entry to exit), agents that are trying to solve the problem (move from entry to exit), and a "best practice" that describes a path with the fewest steps (a series of moves). Agents are boundedly rational with limited memory and their knowledge (gained through personal experience and communication with other agents) at any given time is incomplete and imperfect. Our simulations show that basic knowledge transfer arrangements similar to those in the accounting profession (e.g., partnerships & professional societies) significantly improve agents' ability to solve a problem. We demonstrate how behavioral conformity reduces as task complexity increases but increases when knowledge transfer and retention arrangements are present. The efficiency of the agents' solutions improves, at times dramatically, as knowledge is disseminated more widely among the agents. We present this evidence to illustrate the power of knowledge institutions such as partnerships, professional societies, and professional publications in creating behavioral homogeneity through a dynamic process of knowledge diffusion.

The main implication of our analysis is that the forces that shaped (and likely continue to shape) accounting practice extend far beyond the highly publicized activities of standard-setting bodies. The economic and social forces that generate norms likely shape a given accounting practice long before the standard setter evaluates alternatives and issues a specific standard. The same forces likely also induce commonalities in implementation after a given standard is promulgated. Our analysis highlights new opportunities to research how accounting practice evolves both because of regulation, and more importantly, deeper fundamental forces that induce regularities in accounting choice without explicit direction from a central authority.

The rest of the paper is organized as follows. The next section states our main hypothesis and describes its conceptual and historical underpinnings. We then describe the setup of the agent-based model. The following section provides the evidence from our simulation analysis. We then introduce some extensions to the model and some brief concluding remarks are offered in the final section.

HYPOTHESIS DEVELOPMENT

We develop our main hypothesis in three stages. We first provide a working definition of “norm” and describe the main forces likely to influence the emergence of norms. We next review the knowledge institutions that helped build a broad knowledge base within the U.S. accounting profession over the decades before 1930. Finally, we state our main hypothesis.

What are Norms and How Do They Emerge?

Voluntary accounting norms prevailed before the federal Securities Acts and the first formal U.S. standard setters of the 1930s (Sunder 2005). May (1946, 2-3) notes: "Many accountants were reluctant to admit that accounting was based on nothing of higher order of sanctity than conventions…. Accounting procedures have in the main been the result of common agreement between accountants" (see also Sanders, Hatfield, and Moore 1938, 2).[2] Consistent with this, Madsen (2011) shows that in the 1923 edition of the *Accountants' Handbook*, advocated accounting practices are defended primarily by citation to accounting norms and conventions rather than academics, expert practitioners, regulators, or their consistency within a conceptual framework.

Research on social norms spans several disciplines including sociology, anthropology, and economics. There is no consensus definition of what constitutes a social norm. Hechter and Opp (2001b, 402-404) note that most definitions focus on at least one of three attributes: (1) behavioral regularities (i.e., conformity of behavior among actors), (2) "oughtness" implying a moral dimension to the action, and (3) social sanctions that reward correct actions and/or penalize inappropriate ones. Lewis (1969, 76) defines a convention as a behavioral "regularity" that resolves a recurrent coordination problem; it is common knowledge that everyone conforms (and prefers that others conform) to the convention, and everyone is indifferent between the observed convention and some alternative so long as everyone chooses the same

[2] George O. May chaired the Committee on Accounting Procedure (CAP), which was the first standard-setting body recognized by the SEC. CAP generally eschewed broad conceptual stands, and instead chose positions that could be sustained in practice (Zeff 1972, 140-3).

option. However, some researchers argue that these conditions are not strictly necessary (Jamieson 1975; Gilbert 1983).

Early U.S. accounting norms were not strictly conventions as defined above. Any given accounting norm observed historically may (but need not) solve a coordination problem, knowledge of the norm is often not universal, and the specific form of the norm might matter to individuals and firms because the norm affects wealth (e.g., through rate regulation and taxes). For this paper, we define a "norm" as a behavioral regularity that defines conditional expectations of behavior, others' knowledge of the norm is widespread (but not necessarily universal), and it may (but need not) carry with it moral implications. Our definition comports with less ambitious views where "norms are merely behavioral regularities that generate social expectations without any moral obligations" (Hechter and Opp 2001a, xiii).

Norms often reflect precedent accumulated in a "bottom-up" imitation process, and can be invisible to the actors whose behavior they govern (Richerson and Boyd 2005; Young 2008; Rendell et al. 2010).[3] Several forces influence the emergence of a norm and make some settings more conducive to establishing a norm than others (Hechter and Opp 2001b). One is the strength of ties between members of a group interacting in a network, where weak ties (acquaintances) diffuse information more widely than strong ties (friends), because friends tend to share friends and form small cohesive groups (Granovetter 1973). Another is that norms can help a group to define its identity and socialize new members to the ways of the group (Schudson 2001, 167-168). The most obvious force promoting the emergence of norms is

[3] Sumner (1906, 3-4) writes "From recurrent needs arise habits for the individual and customs for the group, but these results are consequences which were never conscious, and never foreseen or intended. They are not noticed until they have long existed, and it is still longer before they are appreciated."

economic gains that can accrue to an individual or group (Coleman 1990, 241-265; Opp 2001, 236-239).

Norm formation within a social group depends on how individuals acquire knowledge, which is then accumulated, transferred, and stored by the group. Behavioral conformity indicative of a norm represents "routines" that include "forms, rules, procedures, conventions, strategies, and technologies around which organizations are constructed and through which they operate" (Levitt and March 1988, 320). Specifying how an individual acquires knowledge (i.e., "learns") through individual experience and shares knowledge through social interaction is of central importance.[4]

Social learning requires communication of knowledge between members of a group (Rogers 2003, 300-364). Groups and organizations can play a role in social learning because the arrangements they use to manage many individuals' knowledge can improve both individual and group performance (Argote 1999; Argote et al. 2003).

Prior research on how a learning unit (e.g., a professional organization) creates, distributes, and stores knowledge reaches three conclusions relevant to our analysis (Argote and Miron-Spektor 2011, 1128-1131). First, training and education improve an individual's ability to acquire useful knowledge (Nadler et al. 2003). Thus, organizations composed of well-trained individuals are more likely to acquire and retain relevant knowledge that can be transferred to others. Second, relevant knowledge can be either explicit ("know what") or tacit ("know how") (Polanyi, 1958; Vera-Munoz et al. 2006, 135). Explicit knowledge can be

[4] Research suggests that factors such as group size and geographical dispersion, the quality of individuals' memory, and social status of an individual member affect how quickly knowledge sharing in a network converges to behavioral conformity indicative of a norm (Kooti et al. 2012; Lorenz et al. 2011; Montanari and Saberi 2010; Vanderschraf 1995; Villatoro, Sen, and Subater-Mir 2009).

communicated in writing whereas tacit knowledge is transferred more effectively through observation of another's behavior and spoken interaction. Third, knowledge depreciates, which suggests that gains can accrue to groups that embed individual knowledge in a "routine or transactive memory system" (Argote and Miron-Spektor 2011, 1126). Checklists reduce errors by reducing reliance on individual knowledge and memory (Gawande, 2009).

Long-term individual memory has two types: declarative or explicit and procedural or implicit (Graf and Schacter 1985; Schacter 1987).[5] Explicit memory stores information that can be consciously recalled such as facts and events (who won the soccer World Cup), whereas implicit memory comprises unconscious knowledge such as skills (catching a ball). Tulving (1972) further divides explicit memory into episodic memory of personally experienced events (one's first job offer) and semantic memory of facts that do not rely on personal experience (capital of California). Brain lesion and functional Magnetic Resonance Imaging (fMRI) studies show that different kinds of memory are stored in different parts of the brain (see Squire 2009 for a brief recent review).

The construction of social (i.e., "transactive") memory by externally storing the knowledge of experts lets other professionals use this knowledge in remote times and places (Wegner 1986).[6] The development of collective memory among U.S. accountants is central to

[5] Short-term or working memory refers to the ability to temporarily hold limited information in mind to be used for activities such as learning, reasoning and preparing for action (Baddeley and Hitch, 1974)

[6] Wegner (1986, 189) defines a transactive memory system as one where "Other people can be locations of external storage for the individual… (o)ne person has access to information in another's memory by virtue of knowing that the other person is a location for an item with a certain label. This allows both people to depend on communication with each other for the enhancement of their personal memory stores." Wegner et al. (1985) originally developed the concept of a transactive memory system for an intimate dyad or couple. As the Internet improves as an external memory system, people are remembering fewer individual facts but more metadata about how (Google and other search engines) and where (IMDB or other online databases) they can retrieve these facts (Sparrow et al. 2011).

the formation of accounting norms before 1930. Several institutions contributed to transactive memory by enabling the acquisition, distribution, and storage of professional knowledge.

The History of U.S. Accounting Knowledge-Building Institutions

The demand for accounting knowledge and the norms that reflect cumulative knowledge increased beginning in the early-19th century as business organizations grew in size and complexity. Railroads were among the first large American business organizations, starting on the East Coast in the 1830s and then expanding westward through the early 20th century (Ripley 1912; 1915).[7] Technological innovations like electricity, the telephone, and the telegraph also led to the development of new industries in communications, distribution (i.e., retailing), natural resource processing, and mass production of consumer goods (Chandler 1977). Using Census Bureau data, Figure 1 shows that the U.S. economy became more diversified by economic sector, especially from 1839 to 1879, with the expansion of these new innovative industries.

To capture the economic gains associated with new markets, business organizations became larger and more complex (Chandler 1977). Figure 2 displays time-series estimates of mean U.S. firm size using Census Bureau data, which suggest that U.S. firms grew quickly, especially from 1850 to 1900. During this period, business organizations also expanded through

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[7] Canal companies were competing large-scale organizations that appeared a decade or two earlier (Chandler 1977, 33-49). Like the railroads, the canals required large capital investment, but governments financed most of this rather than private investors. Chandler (1977, 120) sees the railroads as the “first modern business enterprises” that used “a large number of salaried managers” and were “the first to have a central office operated by middle managers and commanded by top managers who reported to a board of directors.” Railroads were also “the first American business…to develop financial and statistical flows to control and evaluate the work of the many managers.”

business combinations, initially via trust arrangements (e.g., Standard Oil) and later by direct mergers effected through stock purchases (Navin and Sears 1955).

The demand for accounting expertise also increased as accounting information came to be used increasingly for internal management purposes as well as for external disclosure to capital suppliers and regulators. Railroads were early pioneers in creating internal accounting systems that measured costs of service and activity indicators in the 1850's and 1860's (Chandler 1977, 103-121). European investors sought detailed accounting information to monitor their distant U.S. investments (Baskin and Miranti 1997; Previts and Merino 1998), and large U.S. firms began to attract government scrutiny and regulation based partly on accounting numbers (e.g. Jarrell 1979; Sivakumar and Waymire 2003).

The number of accountants increased to meet the greater demand for accounting expertise. Since many early U.S. accountants had emigrated from Great Britain where professional societies and professional competence requirements existed, they created similar institutions in the U.S. (Edwards 1960). State professional societies started in New York in 1882 and the national American Association of Public Accountants (AAPA) was established in 1886 (Miranti 1986; Previts and Merino 1998, 131-150). New York passed the first CPA law in 1896. By 1916, forty states had issued CPA certificates to individuals who had passed a CPA exam, and by 1930 thousands of similar licenses had been issued (Edwards 1960, Appendix).[8]

[8] Flesher et al. (1996) tabulate the first 129 recipients of CPA certificates during 1896-97 from a listing of all New York CPAs with their certificate numbers and street addresses published in the June 1898 issue of *Accountics: The Office Magazine*. Flesher et al. (1996, p. 255) identify 86 CPA certificates as being issued in 1896, all by waiver of the CPA exam. Edward C. Charles, Joseph Hardcastle and William H. Jasper passed the first CPA exam administered in December 1896 and received their certificates in 1897 (Flesher et al. 1996, p. 253). Christine Ross took the New York CPA exam in June 1898 and received certificate no. 143 on Dec. 21, 1899 to become the first female CPA (Previts et al. 2007).

Canning (1929, 8-9) thought that the knowledge-building institutions developed by the accounting profession led to greater standardization in accounting practices:

> With the increase in the scale of enterprise operations came a need for an expansion of the record-keeping schemes and for the organization of a greater wealth of detail in the records.... With the rise of a specialized group of auditors, experiences began to be exchanged in association meetings and in journals. Certain procedures began to be standardized and fixed. Practices that proved inconvenient or that visibly conduced to disaster were abandoned.

Several pre-1930 professional accounting institutions likely contributed to expanding the professional knowledge base that underlies norm formation. Figure 3 lists several examples of such institutions.[9] We categorize these institutions according to three primary functions (shown in the first column): (1) knowledge acquisition, (2) knowledge dissemination, and (3) knowledge retention. Specific examples are divided into five sub-periods: (1) before 1890, (2) 1890s, (3) 1900s, (4) 1910s, and (5) 1920s.

Efficient knowledge acquisition by new professionals depends on the quality of their education and training. The Wharton School (U. of Pennsylvania) began offering accounting coursework in 1883, and nearly 20 years later the Pennsylvania Institute authorized courses in the four areas covered on the modern exam: accounting theory, practice, auditing, and law.[10] CPA exam requirements increased the overall demand for formal accounting education, and the nationalization of the CPA exam in 1917 encouraged even further growth (Previts and Merino 1998, 198-201). The number of accounting courses offered in universities and colleges grew dramatically after 1900 (see Figure 4).

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[9] Figure 3 is by no means a comprehensive list and only illustrates a few key institutions that helped build a U.S. accounting knowledge base. Also, our partitions of knowledge function do not acknowledge that an institution can play multiple roles. For instance, a compendium that stores knowledge can also aid knowledge acquisition by providing a resource for training and education.

[10] Sampson (1960) discusses other educational initiatives in pre-1900 U.S. accounting.

Knowledge disseminates differently depending on whether the knowledge is explicit or tacit. Disseminating tacit knowledge requires direct interaction because it cannot be effectively transmitted through formulae, diagrams or written instructions (Polanyi, 1958). A professional apprenticeship can be effective in transferring tacit knowledge, which is likely one reason why work experience has always been required to obtain CPA certification. U.S. accountants began forming large professional partnerships, which would also promote ongoing tacit knowledge transfer through strong ties of repeated interaction. The first national accounting firm (Barrow, Wade, Guthrie & Co.) was founded in New York City in 1883 and Price Waterhouse opened a U.S. affiliate (Jones, Caesar & Co.) in 1890 (Edwards 1960, 50).[11] The formation of local and national societies where professionals could meet and discuss current issues would also likely facilitate tacit knowledge sharing.[12] During 1874-89, local accounting societies (forerunners to larger state and national societies) were established in New York and 12 other U.S. cities (Previts and Merino 1998, 136). The first national meeting of professional accountants in 1904 assembled thought leaders to debate the major issues facing the nascent profession (Samuels 1985), and helped diffuse knowledge widely through the weak ties of sporadic interaction.

Printed materials such as textbooks and journals help disseminate explicit knowledge. Classic textbooks by Sprague (1908), Hatfield (1909), Montgomery (1912), Dickinson (1913), and Paton and Stevenson (1918) influenced generations of professionals. Hatfield's *Modern*

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[11] Causholli (2012) shows that auditing firms generate tacit knowledge and that the institutionalization of tacit knowledge is crucial for firm efficiency.

[12] Collins (2010) distinguishes between relational tacit knowledge (things that could be described if someone tried hard enough), somatic tacit knowledge (things our bodies can do but we cannot describe how, like balancing on a bike), and collective tacit knowledge (knowledge we draw upon that is the property of society, such as the rules for language). Collins argues that collective tacit knowledge can only be acquired through socialization, which helps explain why professions place so much emphasis on partnerships, meetings and societies to inculcate good practices.

Accounting was widely used decades after its initial publication (Zeff 2000) and *Montgomery's Auditing* is still in print (O'Reilly et al. 1999). However, there was a dramatic increase in the number of works devoted to accounting starting in the 1870s relative to earlier in the 19th century (see Figure 5). Articles in the *Journal of Accountancy* (first published in 1905) also fostered continuing professional education.[13] Its "Student's Department" was a monthly column started in 1914 that leveraged the content of the CPA exam to aid the training of young professionals (Moonitz 1970).

A visible institution that facilitated knowledge retention was the American Institute Library founded in 1918.[14] Institute librarians compiled the *Special Bulletins* on accounting practice in the 1920s and they produced a major bibliography of published work on accounting, *The Accountant's Index*, in 1921 (Carey 1969, 138-9).[15] A major compendium of practice, *The Accountant's Handbook*, was first published in 1923, and still continues today.[16] Figure 5 shows that the accounting literature, measured as the number of bound works on accounting, expanded rapidly from the 1860s to the 1920s.

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[13] A competing accounting association, the Institute of Accounts (founded in 1882 in New York as the Institute of Accountants and Bookkeepers) had earlier published a monthly journal named *Accountics* (April 1897-September 1900). Romeo and Kyj (1998 fn. 4) list other early U.S. accounting journals edited by members of the Institute of Accounts including *The Bookkeeper* (July 1880-May 1883) renamed *American Counting-Room* (July 1883-November 1883), *The Office* (July 1886-May 1891) renamed *Business* (January 1891-December 1901), *Commerce, Accounts and Finance* (January 1901-April 1903), *Business World* (January 1902-December 1906) and *The New York Accountants and Bookkeepers' Journal* (February 1903-October 1904). Romeo and Kyj (2000) compile a partial list of lectures at the Institute of Accounts monthly meetings from 1882 to 1907 from their publications in the journals listed above. The oldest surviving British accounting periodical is *The Accountant* (started October 1874).

[14] Carey (1969, 135-6) writes that the AIA Library was the result of efforts by George O. May and links the need for this institution to knowledge storage when he writes that it was clear "that the growing accounting profession needed urgently a central repository of its accumulated knowledge." AAPA directors had resolved in 1896 to seek headquarters space in New York "for the purpose of acquiring a library and for general purposes" (Bonner 2007).

[15] The major accounting firms started to integrate communication in this period – e.g., Price Waterhouse held annual meetings involving partners and senior managers, and they initiated a regular newsletter updating personnel on practice developments (DeMond 1951, 69 & 113-4).

[16] The first editor of *The Accountant's Handbook* described its function as aiding professionals who lacked "ready access to libraries covering all the topics which they may have occasion to look up" (Saliers, 1923, v).

These institutions influenced historical U.S. accounting practices – e.g., in the case of consolidated reporting, which evolved spontaneously from practice (Kracke 1938, 372-373). Consolidated financial statements are now commonplace but were unheard of before 1900 because ownership of common stock by another corporation was illegal until 1889 (Navin and Sears 1955). After J. P. Morgan combined several existing steel makers into a single entity in 1901 (Chernow 1990, 81-86), U.S. Steel became the first major American corporation to prepare consolidated financial statements for external disclosure in 1902. Shareholders of U.S. Steel selected Price Waterhouse (a British firm at the time) to perform the firm's annual audit.[17] By 1930, consolidated reports were common among large U.S. firms. For example, of the 540 NYSE-listed firms studied by Barton and Waymire (2004), 394 (73%) issued financial statements labeled as either "consolidated" or "combined" (per *Moody's* manuals for 1927 and 1928).

The use of consolidated financial reports was encouraged by speeches at professional meetings and in *Journal of Accountancy* articles. Early publications by Dickinson (1904; 1906) were especially important since he, as senior partner for Price Waterhouse's U.S. affiliate, had led the U.S. Steel audit (DeMond 1951, 58-64). William Lybrand's talk on consolidated reporting at the 1908 meetings of the American Association of Public Accountants was published as a three-part article in the *Journal of Accountancy* (Lybrand 1908a; 1908b; 1909).[18] A four-part article on consolidations spanning 64 pages appeared in the Student's Department in 1918

[17] According to DeMond (1951, 61-62), Price Waterhouse had some experience with preparing consolidated financial statements (perhaps in their U.K. practice), but none that involved a large firm like U.S. Steel.

[18] The first Lybrand paper was reprinted in the British journal, *The Accountant*, in December 1908. *The Accountant* had earlier published a copy of a lecture by A. L. Dickinson (1905) on consolidated reporting. Walker (1978/2006, 39-40) reports that these were the first articles on consolidated reporting to appear in British accounting journals. The U.K. allowed intercorporate investments before New Jersey did, but these investments were usually reported at historical cost as a single line item on the balance sheet (Walker 1978/2006). Consolidated reporting did not assume importance in Britain until the 1930s (Walker 1978/2006; Camfferman and Zeff 2003).

(Walton 1918a; 1918b; 1918c; 1918d).[19] State CPA exams from the early 20th century included questions on consolidated reporting.[20] Introductory textbooks discussed consolidated reporting (e.g., Hatfield 1909, 179-182). Advanced textbooks devoted multiple chapters to the topic (Kester 1918, 507-555 & 600-619) and a book by Finney (1922) was devoted entirely to the subject of consolidations.[21]

The history of consolidated financial reporting illustrates two important points. First, consolidated reporting "bubbled up" from individual attempts to solve a problem that had arisen in practice.[22] Second, many of the institutions listed in Figure 3 taught practitioners how to address this issue. While not conclusive, we believe that this historical evidence establishes a temporal association between professional knowledge sharing about consolidated reporting and the spread of consolidated financial reporting among major U.S. firms.

Hypothesis

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[19] Contemporary writers also expressed skepticism about holding company financial statements. A *Journal of Accountancy* column by Thomas Mitchell during 1906-07 was devoted to a "critical review" of American corporate reports (*Journal of Accountancy*, October 1906, p. 458). Consolidation reporting figured prominently in the October 1906, November 1906, April 1907, and July 1907 columns written by Mitchell. Freeman (1914) also discussed the limitations of financial statements by holding companies

[20] The Pennsylvania CPA exam of May 1906 included a question about the financial statement effects of an electric railway buying eighty percent of the outstanding equity of another such firm (see "Pennsylvania C.P.A. Exam Questions," *Journal of Accountancy*, July 1906). Additional questions on consolidated reporting were included in the 1906 Illinois exam and the 1908 Michigan exam shown in the November 1907 and September 1908 issues of the *Journal of Accountancy*.

[21] Early editions of *The Accountant's Handbook* also provided extensive discussion and illustration of consolidated financial reporting techniques (Saliers 1923, 1089-1164; Paton 1932, 1015-1072).

[22] The case of consolidated reporting is not unique. For example, depreciation accounting was a major issue in the early 20th century (Watts and Zimmerman 1979). When categorizing the 815 items included in the "Student's Department" section of the *Journal of Accountancy* during 1914-22 by balance sheet topic, we found property, plant, and equipment was named in 246 items (second only to Earned Surplus with 377). When we classified items by income statement categories, depreciation expense was named in 173 items. Walsh and Jeacle (2003) trace the spread of the retail inventory method in the U.S. from a handful of department stores in 1920 to over 70% by 1927 (Friedman 1929) and stress the importance of preceding institutional developments in the accounting profession and the merchandising industry. Waymire and Basu (2008) trace the spread of R&D expensing in the U.S.

Our main hypothesis is that accounting norms spread through knowledge-building institutions that arose in the U.S. accounting profession before 1930. Stated formally, our (alternative) hypothesis is:

> Institutions that enable education of, communication between, and knowledge retention by accounting professionals lead to greater conformity of accounting policy choices.

The ideal dataset to test this hypothesis would include two primary measures. First, complete time series of accounting policies measured periodically from a firm's birth to death would be available for a large representative sample of firms. Second, the complete professional histories (i.e., education, work experience, professional memberships, and professional interactions) would be available for the people who determined each firm's accounting policies.[23] This dataset could identify how accounting choices vary cross-sectionally at a given moment and which forces drive the evolution of accounting practices over time.[24]

Unfortunately, such a dataset cannot be constructed. Since we do not have historical data that lets us directly study how professional knowledge-building institutions led to accounting norms, we use a 'history-friendly' agent-based model that we calibrate using U.S. accounting history (Malebra et al. 1999).[25] Our simulations let us study "mechanisms that translate unorganized individual behavior into collective results" (Schelling 1971, p. 145) and

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[23] Reppenhagen (2010) documents the diffusion of stock option expensing through several information channels with direct communication (e.g., board interlocks, common external auditors, geographic proximity) as well as inferring knowledge from reference groups (e.g., firms in the same industry and large, successful firms), but even with large modern databases, this study leaves several diffusion channels unexplored.

[24] In short, our hypothetical dataset would allow a researcher to establish lines of descent for accounting practices based on cultural phylogenies of accounting practice as has been hypothesized more broadly for human culture (Boyd et al. 1997).

[25] Brenner and Werker (2007) classify agent-based models into five types based on the types of calibration and inference, of which 'history-friendly' is one. Agent-based models go back at least to Schelling's (1971) model demonstrating that segregated outcomes can emerge with little intent to discriminate on the basis of personal characteristics.

clarify how historical accounting knowledge-building institutions could facilitate behavioral conformity indicative of a norm.

CALIBRATION OF THE AGENT-BASED MODEL

Our simulation analysis lets us directly observe a dynamic process whereby sharing of explicit knowledge among agents in a network can lead to behavioral homogeneity. While agent-based models have been used sparingly in the accounting literature (e.g. Davis *et al*. 2003; Dickhaut and Xin 2009), we can study interactions that are difficult to observe in real life while experimentally "controlling" the environment and manipulating variables of interest. We reason by analogy in using outcomes from simulations calibrated using U.S. accounting history to infer broad properties of accounting evolution.[26] The Appendix (intended as an online supplement) provides a detailed description of our agent-based model to facilitate replication (our current code is available upon request and our final code will be archived online).[27]

Agents face a problem with multiple potential solutions that can be discovered by searching. This problem is analogous to one that a professional attempts to solve (e.g., how to account for a new transaction) when some solutions are more "efficient" than others.[28] We analyze how the homogeneity and efficiency of agents' solutions is affected by differing levels of task complexity, increased numbers of agents, how widely agents can share their explicit

[26] Our approach complements that of Jamal, Maier, and Sunder (2003; 2005), who use a field study of Internet privacy policies in the U.S. and U.K. as an analogy for accounting norm evolution. Our approach differs from Jamal, Maier, and Sunder in that we examine a controlled setting with an environment and institutions similar to those observed in the history of U.S. accounting practice.

[27] Our agent-based model is implemented using a program called NetLogo (version 4.1.3) (Wilensky 1999).

[28] Kuhn (1962, 35-42) characterizes normal science as 'puzzle-solving' where 'puzzle-solvers' are familiar with similar puzzles and their solutions, expect to have a reasonable chance of solving the puzzle and the likelihood of solving the problem depends on the ability of the 'puzzle-solver.'

knowledge (i.e. knowledge dissemination), and the amount of explicit memory available to recall what has been learned previously (i.e., knowledge retention).

The specific task involves navigation through a rectangular N x N maze of fully connected nodes, where N is an odd number. Figure 6 provides a “bird’s eye view” of a maze where N = 5 yielding N^2 = 25 nodes. Each node is linked with two to four neighboring nodes, depending on whether it is an interior node (four links), an edge node (three links), or a corner node (two links). A link between two adjacent nodes lets agents travel between them in either direction. There are 40 unique links between nodes of the maze shown in Figure 6.

Nodes are numbered horizontally and vertically starting from the bottom-left corner at (1,1) and ascending towards the right and top to (5,5). Agents enter at the center of the maze at node (3,3) and can leave through a regular exit at node (5,5) or at a closer, randomly determined “shortcut” exit, which in Figure 6 is at node (3,1). The shortcut exit can be thought of as an innovation that, if discovered, can be used to exit more quickly than the regular exit at node (5,5). Each agent knows tacitly how to move from a given node across links to neighboring nodes and can recognize an exit when one is reached.

On an agent’s first run through the maze, each move is at random to an available adjacent node. For example, when entering at node (3,3) in Figure 6, the agent moves with equal probability up to node (3,4), down to (3,2), right to (4,3), or left to (2,3). The agent continues moving randomly until she reaches an exit.

Each agent can remember only her first M moves within the maze. If an agent happens on a path with fewer than M moves, the full path can be stored in memory. While running the maze, an agent may travel in a loop and reach a particular node a second time. In this situation, the steps taken between her first and second arrival at the node were redundant. We assume agents can recognize such loops after they have exited the maze, and then remove the wasted steps from their memory when their episodic memory is large enough to do so. As a result, the path an agent remembers can be shorter than the path she traveled.[29] The elimination of loops represents learning based on personal experience. This process is repeated for each agent in the population. For example, if there are 20 agents in the population, each runs the maze independently and might have a unique path from entry to exit on the first round.

On the next round, the agent follows her remembered path until she exits or, if she reaches the end of her remembered path without exiting, resumes choosing links randomly until she reaches an exit. We assume that each agent prefers to reduce the number of steps taken to exit the maze (e.g., to reduce the opportunity cost of time). An agent's ability to run the maze in fewer steps will depend on what she has learned from her own past experience.

In some conditions, we allow agents to communicate with each other after having run the maze. An agent's knowledge now depends on her own experience as well as that of the agents with whom she has communicated because she stores in explicit memory the shortest path she knows. Communication enables social learning from the group's transactive memory.

All agents run the maze repeatedly until no path is updated after additional runs – i.e., each agent has settled on a final path, a condition we label "stasis." After stasis is achieved, we run the entire process again using a new maze with a new (randomly chosen) shortcut location and all agents having no stored path in memory. We run this new setup until stasis occurs. We

[29] For example, consider an agent who can remember 20 moves and exits the maze after 30 moves including loops. The agent will remember her first 20 moves and remove loops from that section of her path. The remembered path with loops removed will be less than 20 (or equal to 20 if there were no loops) and it will be incomplete since she does not remember the end of the path.

repeat this process a total of 1,000 times to obtain a representative distribution of the number of different paths chosen by agents. This distribution provides a direct measure of how much agent behavior converges because of knowledge communication and social learning.

Our simulation analysis starts with a Baseline model that represents a simple environment where only a few agents run a small maze independently of one another, which sets a benchmark for evaluating agent behavior in more complex settings. The historical analog for the Baseline model is the U.S. market for accounting knowledge around 1850. The Baseline (1850) model employs a simple 5x5 matrix and a small population of 50 agents. We limit each agent's episodic memory to 20 moves and do not let agents communicate. Thus, changes in agent behavior in the Baseline model are based solely on learning from personal experience, which is one component of knowledge acquisition.

SIMULATION EVIDENCE

Table 1 provides summary statistics on task performance in the Baseline model. The first measure in Table 1 is the diversity (inverse of conformity) of the agents' paths. We compare the paths (i.e., a sequential list of all the nodes) that agents follow to solve the maze and count the number of unique paths in each round. The number of unique paths reflects the diverse solutions that agents discovered solely through their own experiences. In the first round, the 50 agents use an average of 46.2 different paths, and this number falls to only 26 by the final round. That is, even after numerous trips through the maze in the Baseline model, agents often choose different paths.

In terms of efficiency, nearly two-thirds of the agents exit at the shortcut exit, and nearly half of the agents exiting at the shortcut in the final round take the fewest steps they could. Agents take far fewer steps to exit the maze after multiple rounds in the Baseline model. On average across 1000 mazes, in the final round the median agent travels across four nodes from entry to exit compared to 18.9 nodes in the first round.

Specific levels for the four parameters across different simulations are shown in Table 2. New simulations beyond the Baseline model manipulate four parameters: (1) the extent and type of communication between agents (C), (2) the number of moves that can be stored in individual agents' memory (M), (3) task complexity represented by the square root of the number of nodes in the maze (N), and (4) population size given by the number of agents (P). We focus on primary knowledge-building characteristics of endogenous accounting institutions – i.e., the nature of communication (C) and the extent of memory (M) possessed by agents. Task complexity (N) and population size (P) are environmental factors that we hold constant while evaluating the effects of changes in communication and agent memory on the diversity and efficiency of agents' solutions.

Panel A of Table 3 reports results for two models that measure the impact of greater professional communication after 1870 when local accounting societies were established in several major U.S. cities, such as the Bookkeepers Beneficial Association of Philadelphia in 1874 (Previts & Merino 1998, p. 136). The Baseline (1850) model already described is a benchmark where no communication occurs. Alternative1 (1870) is a simulation model where "neighbors" exchange limited data with a low probability (p = 0.10). Task complexity, population size, and agent memory are held constant at their lowest values in comparing Alternative1 and the Baseline model.

To define neighbors, each agent is assigned a number between 1 and P, and agent 1 can communicate with agent 2, agent 3 talks to agent 4, and so forth. Each agent remembers two pieces of information, her remembered path (up to M moves) and the total number of steps including loops (T) from her last round. After removing loops from her remembered path (M), the agent has an updated path (M'). Each agent compares the number of moves it took to complete the maze with loops removed (M') to the corresponding number of moves taken by her neighbor.[30] The faster (fastest) agent conveys the explicit knowledge of its path to the slower agent(s), which the slower agent(s) then memorizes.[31] If an agent's current path is the shortest or joint-shortest of the alternatives available, then the agent does not switch. The agent uses the path stored in her memory to try to find an exit in the next round.

Panel A of Table 3 shows comparative static results for Alternative1 and the Baseline model. Even limited communication between neighbors reduces diversity in agents' paths through the maze. On average, the 50 agents follow 46.2 different paths in the first round of the Baseline and Alternative1 models. However, the number of unique paths declines by 68% when stasis is reached in the Alternative1 model, which is over one and a half times the improvement for the Baseline model. Agents in the Alternative1 model are also more efficient

[30] An agent always prefers a complete path to an incomplete path. If an agent is comparing two incomplete paths, she chooses the path with the lowest number of total moves (T). If the two paths have the same number of moves (T), then she keeps her path.

[31] We model agents who can store only 20 moves in explicit memory, so that semantic memory (another agent's path) displaces episodic memory (one's own path). We also assume that an agent prefers to follow a complete path stored in memory to exploring and risking ending up with an incomplete path.

as measured by the percentage using the shortcut and the median number of nodes traversed, but these effects are less pronounced.

Panel B of Table 3 reports results for two models that we use to evaluate the effects of more widespread communication after 1880. The benchmark for this comparison, Alternative2 (1880), is a model where agent memory is still limited to 20 moves, population size remains at 50 agents, and communication occurs only between neighbors as in Alternative1 (see Panel A) but agents face a more complex task (N = 15 or N^2 = 225 nodes in maze). Alternative2 is identical to Alternative1 except that task complexity is greater for Alternative2. The 225-node maze represents a more complex business environment at the end of the 19th century (see Figure 2 where average client firm size during 1880-90 was double that in 1850).

Alternative3 (1890) is identical to Alternative2 in terms of task complexity (N = 15) and population size (50 agents). We do not change population size because we expect that the number of accountants increased rapidly only after 1900 as the CPA exam became more important. Alternative 3 differs from Alternative 2 because it allows moderate communication with and learning from "partners" and assumes a moderate increase in explicit memory (100 vs. 20 moves remembered).[32] The first large U.S. accounting firms appeared in the 1880s and they presumably relied on written communication (e.g., practice manuals) to a greater degree. We increase agents' explicit memory to 100 moves to represent partnership memory aids as well as the growth in the professional literature from around 20 accounting works in 1869 to close to 100 works by 1889 (see Figure 5). To model knowledge sharing within partnerships, we form

[32] Although we increase memory exogenously, Dávid-Barrett and Dunbar (2013) use an agent-based model to show that memory constraints limit the amount of social learning that can occur and that memory increases endogenously only when the benefits through social learning exceed the costs of increased memory.

larger groups of agents that share information after each round.[33] These groups are fixed for a given maze so that agents communicate repeatedly with the same partners after each round. Partnerships consist of five adjacent agents each and ten percent of the agent population is assigned to partnerships while the remaining 90% is not. Partners share information in the same way as neighbors described previously after neighbors communicate with each other.

Panel B of Table 3 provides results for the Alternative3 and Alternative2 models. As in Panel A, we find that improved communication reduces diversity in the agents' paths. In this comparison, more extensive communication in Alternative3 reduces the number of unique paths by 49% versus only 18% for Alternative2. While there is little difference between Alternative3 and Alternative2 in the number of agents using the shortcut exit, there is a substantial reduction in the number of moves to reach an exit.

We seek to identify the impact of expanding communication to the entire society of professionals in our final comparison. The two models compared, Alternative5 (1920) and Alternative4 (1900), are ones where task complexity is high (N = 15 or N^2 = 225 nodes), all agents have high memory (100 moves), but now the population has expanded (500 agents). The larger population is consistent with the number of CPA licenses conferred growing from about 50 in the early years to over 500 after 1920 (Edwards 1960). In Alternative5, agents share explicit information at the society level – e.g., through publications such as the *Journal of Accountancy* and interaction at national professional meetings.[34] We model this society-level exchange of explicit knowledge by having agents communicate with one randomly chosen

[33] Partnerships likely encouraged the sharing of both tacit and explicit knowledge among partners, which have synergistic effects in learning (e.g. Homer and Ramsay 1999; Slusarz and Sun 2001). However, our analysis focuses on increases in explicit memory and explicit knowledge that are easier to model (Dávid-Barrett and Dunbar 2013).

[34] The readership of the *Journal of Accountancy* increased from around 2,000 in the inaugural year of 1905 to around 14,000 in the 1920s (Shildneck 2005).

"distant" agent after each round in addition to their partners and neighbors. Distant agents are neither "neighbors" nor "partners." We model distance as a circular network using agent numbers and use a random number generator to choose how "far away" the distant agent is.

Panel C of Table 3 reports results for the Alternative5 and Alternative4 models. Behavioral homogeneity differs dramatically between these two models. By the final round, the 500 agents in the Alternative5 model follow an average of 7.8 different paths to exit compared to 211.3 paths for the Alternative4 model. The number of unique solutions in Alternative5 is roughly the number of methods used to account for depreciation or inventory today. In addition, Alternative5 agents in the final round exit at the shortcut almost universally (99%) and do so using almost half the moves of their Alternative4 counterparts (7.5 vs. 14.5 steps).[35] The rapid spread of efficient solutions recalls the rapid spread of the more efficient retail inventory method among U.S. department stores during the 1920s (Friedman 1929).

The evidence in Panel C of Table 3 is the most important provided by our simulation models. It illustrates the power of institutions that disseminate knowledge broadly through weak ties (acquaintances) in altering the behavior of individuals and the population as a whole.

MODEL EXTENSIONS

One possible critique of our simulations is that our results are an artifact of the particular parameters we used. While we tried to calibrate parameters based on accounting history (see figures 1, 2, 4, and 5) to reduce this possibility, in this section we evaluate the

[35] This dramatic effect is consistent with the arguments and findings in Boyd, Richerson & Henrich (2011) that without our proclivity for social learning, humans could not have adapted as effectively to so many diverse environments, far beyond the capability of any other species.

sensitivity of our results to a range of parameter values. Besides providing evidence that our main results are robust, these supplemental results are also theoretically interesting.

We explore how sensitive the results of the Alternative5 model (complex maze, large population, most knowledge sharing) are to changes in our parameters. We believe that this model most closely resembles modern times, so we use it as a benchmark to explore the effects of parameter variation. We explore the impact of three variations: the extent of society sharing, incorrect or misleading information, and heterogeneity in agents' memory.

The Extent of Society Sharing

The Alternative5 model lets all agents communicate with a "distant" agent for society sharing. The institutional analogue is a profession-wide publication like *Journal of Accountancy* or a society meeting where every accountant gets to speak with at least one other previously unknown accountant. We examine how reducing communication to distant agents impacts our simulation results, analogous to subscribers not reading all issues of the journal or professionals skipping a national meeting. We ran several simulations (1000 repetitions for each setup) changing the probability that each agent communicates with a distant agent from 0 to 100%, incremented by 5%. Weak ties theory (Granovetter 1973) and the small-world phenomenon (Milgram 1967, Watts and Strogatz 1998) predicts that even when only a few distant agents communicate with each other, the population will likely converge on effective solutions. This occurs because society-level communication connects previously disjoint clusters of agents (our partnerships and neighbors).

The results of this sensitivity analysis are presented in Figure 7. The horizontal axis shows the proportion of society sharing while the left vertical axis presents the average number of unique paths in the final round. The society sharing level of 0 is Alternative4 (value of 211.3 in Panel C of Table 3) and the society sharing level of 100 is Alternative5 (value of 7.8 in the same panel). Dramatically, minimal society sharing yields most of the benefits of society sharing as shown by the solid red line. For example, a 5% level of society sharing results in 11.3 unique paths on average or a 97.7% improvement from period 1 compared to a 98.4% improvement for 100% society sharing. The right vertical axis presents the average rounds needed to achieve stasis and shows that societies with modest sharing (5%) take longer to converge. No additional time is needed for society sharing above a 50% level, as shown by the dotted blue line. The average number of median moves and percentage of agents using the shortcut exit for the 5% society sharing level similarly converge to nearly the level achieved for 100% society sharing (untabulated). As expected, these results suggest that minimal society sharing generates most of the gains of distant communication. The practical implication is that even sporadic professional meetings can lead to rapid and widespread sharing of explicit knowledge that promotes the spontaneous emergence of accounting norms.

Communication Fidelity

In our simulations, agents communicate perfectly (e.g., with no loss of information). However, in reality data may become garbled, either intentionally or unintentionally. Bounded information processing can cause mistakes and competitive pressures may induce deception. We analyze the impact of unintentional errors on our results by randomly inserting one erroneous link into randomly selected paths when they are communicated. We introduce errors only for society sharing since unintentional errors are more likely to occur with one-time meetings. Repeated neighbor and partner information sharing should reduce the incentives to intentionally misreport. We examine the results across a range of fidelity rates (0 to 50%).[36]

The results of this analysis are presented in Figure 8. The horizontal axis shows the proportion of society sharing with an error. The error level of 0 is the Alternative5 model (value of 7.8 in Panel C of Table 3). The left vertical axis represents the average number of unique paths in the final round, which go up steadily as communication errors increase as shown by the solid red line. The right vertical axis measures the average number of rounds needed to achieve stasis, which increases with the frequency of communication errors as shown by the dotted blue line. From a practical perspective, these results suggest that oral communications such as talks at national meetings would likely spread explicit knowledge less accurately than edited articles in professional journals.

Heterogeneity in Explicit Memory

The Alternative5 model specifies high explicit memory (i.e., 100 moves) for all agents. In reality, information processing likely varies across individuals and groups. Some accounting firms likely excelled in acquiring and storing knowledge. We analyze how changing the proportions of agents (from 0 to 100) with high memory (i.e., 100 moves) against low memory (i.e., 20 moves) changes the results. This analysis lets us compare individual memory and social

[36] While the upper bound of 50% differs from the upper bounds of the other extensions, we believe it is actually conservative as the notion that even half of the communications containing errors seems quite high for a profession.to effectively share knowledge.

memory more directly. We expect that a small increase in explicit memory will produce large benefits because explicit knowledge will disperse quickly across the network of agents.

The results of this sensitivity analysis are presented in Figure 9. The horizontal axis shows the proportion of agents with high memory of 100 moves (all other agents have low memory of 20 moves). The left vertical axis indexes the average number of unique paths in the final round. The memory proportion of 100 is the Alternative5 model (value of 7.8 in Panel C of Table 3). Less memory leads to fewer unique paths in the population as shown by the solid red line, likely because agents can remember fewer long paths. The right vertical axis indexes the number of rounds needed to achieve stasis. The dotted blue line shows that simulations with low memory take longer to achieve stasis, likely because agents that do not happen on short paths in the first round take longer to find short paths in subsequent rounds when they cannot remember complete paths.

Comparison of Extensions

To compare the efficiency effects of each parameter, Figure 10 displays the solution efficiency (median number of moves in final round) across the three extensions: the extent of society sharing, communication errors in society sharing, and how much memory agents have. The horizontal axis represents the proportion from 0 to 100 for each parameter we analyzed. The vertical axis presents the median number of moves agents needed to complete the maze in the final round averaged across 1000 repetitions for each setting. While many of the values appear economically equal, some of the differences are statistically significant. While efficiency varies significantly during intermediate rounds because of different convergence speeds, many of those differences vanish once the simulations reach stasis. The lone exception is when society sharing is not present (society sharing=0).

SUMMARY AND CONCLUDING REMARKS

Our goal is to better understand the historical process through which voluntary U.S. accounting norms emerged before the first standard-setters were established in the 1930s. We propose that accounting norms emerged in U.S. practice through accounting knowledge-building institutions that evolved beginning in the 1850s. Our main hypothesis is that the supply of accounting knowledge was mediated in part through these institutions, which enabled knowledge acquisition, dissemination, and retention and led to the emergence of accounting norms. These institutions effectively increased the scale, scope, and durability of knowledge possessed by the U.S. accounting profession and used by its members to solve problems that arose in practice.

We develop our main hypothesis in two stages. First, we chronicle the development of specific institutions that promoted knowledge acquisition, dissemination, and retention among U.S. accounting professionals and describe the state of practice regarding accounting norms before 1930 based on data in contemporary professional publications. Second, we document the importance of knowledge institutions in a case study of consolidated reporting.

We use historical data acquired in developing our hypothesis to calibrate a 'history-friendly' agent-based model that simulates how knowledge sharing among agents in a network can lead to behavioral homogeneity indicative of a norm. Our simulations reveal several interesting regularities. We document how basic knowledge-sharing mechanisms present in the accounting profession (e.g., partnerships & professional societies) significantly improve the performance of our simulated agents. While increased environmental complexity generates less homogeneous behavior, mechanisms that broadly disseminate knowledge can dramatically increase the homogeneity of behavior. The efficiency of the agents' solutions improves significantly as knowledge is disseminated more widely. We present these results as illustrating how knowledge-sharing mechanisms such as partnerships, professional societies, and professional publications enable convergence on efficient solutions through a dynamic process of diffusion across accounting practitioners.

Our simulation analysis suggests some fruitful directions for future research to better link accounting history with underlying processes of cultural evolution. An advantage of agent-based models is their flexibility and our parsimonious model can be modified easily to study other aspects of professional knowledge accumulation. Our model focuses on how various knowledge-sharing mechanisms affect behavioral homogeneity. Future research could examine professional knowledge sharing under more complex conditions.

As one example, our mazes are stable over time unlike real economies that change unpredictably requiring accountants to adapt existing accounting methods to deal with new transactions. One could directly study how "robust" maze solutions are to changes in economic conditions. In addition, different methods for identifying maze solutions or for sharing knowledge could differentially impact behavioral homogeneity, efficiency, and robustness. While we study how "bottom up" processes can generate correlated behavior, a modified model could also examine how a centralized standard-setter influences the homogeneity, efficiency, and robustness of the solutions discovered and shared by agents.

APPENDIX
Detailed description of the agent-based model simulation

We describe our model in detail so that other investigators can replicate and extend our analysis. As explained in Section 5, we use an agent-based model to study the homogeneity and efficiency of agent solutions in sets of mazes. We implement our agent-based model using NetLogo (version 4.1.3), an open-source software available for download from the Center for Connected Learning and Computer-Based Modeling at Northwestern University (Wilensky 1999). We begin by explaining the logic of the program, and then explain the five parts of the program and how they fit within this logical framework.

Program Logic

The model permits a user to easily specify simulation parameters and run repeated simulations. Once the user selects a set of parameters and begins the simulation, the program generates 1,000 different mazes. Each maze has an entrance in the center, an exit at the upper right corner, and a randomly located shortcut exit. The location of the shortcut exit is the only way in which the 1,000 mazes differ. A simulation "round" begins when we place agents into our first maze at the entrance point and have them step through the maze using decision rules explained below. A simulation round ends when all agents have arrived at either the corner or shortcut maze exits. After each round, the program records results for the round and agents may share their solutions with other agents. Still using our first maze, we run additional "rounds" to allow agents to continue learning shorter paths through the maze until all agents have exhausted their opportunities to learn. We call this point "stasis" and we recognize it when we observe no changes in any agent paths over 5 simulation rounds. Under some conditions (explained below), stasis cannot be achieved. When this happens, we terminate simulation of a given maze after 75 rounds. We repeat this process for each of our 1,000 mazes.

A custom user interface allows a user to choose a value for the following variables: number of simulation "rounds" to run for a given parameterization (we always use 1,000); number of total nodes (N^2) in the maze (N must be an odd integer); the number of agents solving the maze (P); the number of moves each agent can remember signifying her memory (M); the probability that an agent will communicate with her neighbor; the probability that an agent will be part of a partnership within which she communicates and the size of partnerships; and the probability that an agent will communicate with a distant agent (our proxy for society sharing). The remainder of the appendix describes the program's five parts: maze setup, agent movement, agent memory processing, agent communication, and result reporting.

Maze Setup

The maze setup portion of the program creates a maze by placing the user-specified number of maze nodes in an N x N matrix and creating connections between adjacent nodes across which agents can travel (2 connections for corner nodes, 3 for side nodes, and 4 for inner nodes), designates which nodes will be used as maze entrance, exit, and shortcut exit, and places the user-specified number of agents on the entrance node. Nodes are numbered in an (x,y) coordinate system with the bottom-left corner numbered (1,1). The entrance node is always at the center of the maze—the node with (x, y) coordinates ([N + 1] / 2, [N + 1] / 2). The exit node is always in the upper right corner of the maze—the node with (x, y) coordinates (N, N). The shortcut exit is a node that is randomly selected using NetLogo's native random number generator. The shortcut exit can be located at any node except that it cannot be the nodes already designated as the entrance or corner exit. We specify a random number "seed" (which itself is a randomly generated number from a different program) for each simulation round and record it with the simulation results. Given this random number seed, we can replicate the simulation round produced using it precisely. Our use of a list of pre-specified random number seeds also enables us to ensure that, given a maze size N, the set of 1,000 mazes used in our simulations is identical no matter the values for other simulation parameters, increasing the comparability of results across different experimental conditions.

Agent Movement

Agents move through the maze simultaneously, with each agent taking her first step, waiting for all other agents to take their first steps, then taking her second step and waiting, with the process repeated until all agents have found an exit node. The code for agent movement is divided into two parts, instructions for agents *not* following a path stored in their memory, and instructions for agents following a path stored in their memory. When an agent without a path stored in memory makes movement decisions, she first observes and records her current location in memory, then moves to a randomly chosen adjacent node. She repeats this process until she finds herself located at an exit node, at which point she stops moving. If an agent, before she reaches an exit, finds that she has filled her available memory, she cannot learn more about the maze and stops remembering further data, but continues moving randomly until she reaches a maze exit. As a consequence, when an agent exits the maze, she remembers either her entire sequence of moves through the maze (a complete path) and the number of moves in her memory (M) equals the number of moves she made (T), or she remembers only the first M moves she made (an incomplete path) and the number of moves in her memory (M) is less than the number of moves she made (T).

Once she has exited a given maze the first time, an agent will have a path stored in memory that may be complete or incomplete. When an agent enters a maze with a remembered path, her decision rule is simply to move sequentially to the next node in her remembered path. She continues to move along the nodes in memory until either she reaches an exit node and stops moving (when she remembers a complete path) or until she reaches the end of her remembered path without reaching an exit (when she remembers an incomplete path). When an agent reaches the end of her remembered path but has not yet reached an exit node, she reverts to random movements until she finds an exit.

Agent Memory Processing

Each time an agent reaches an exit, she examines her memory to try to shorten her path. She accomplishes this by sequentially considering each node to which she remembers moving, beginning with her first step, and checking whether she reached the same node later in her episodic memory. If she remembers visiting a given node twice, she recognizes that she traveled in a loop, and the steps between two successive arrivals at the node were unnecessary. To shorten her remembered path, she deletes the redundant steps from her memory. The ability to remove loops from remembered steps constitutes an agent's capacity to learn from her own experience.

Loop removal enables most agents that do not remember a complete path after the first round to eventually find and remember a complete path through the maze on their own. Without loop removal, an agent remembering an incomplete path would deterministically follow the same incomplete path in every simulation round and could not learn new information with additional trips through the maze. With loop removal, an agent remembering an incomplete path can usually remove some loops from her memory, shortening her remembered path and making some memory available. She can use this free memory to record incremental steps at the end of her remembered path on her next round, which enables her to detect new loops that can be eliminated or to locate an exit.

If an agent fills her memory with an incomplete path containing no loops, the agent cannot learn new information by travelling the maze in additional rounds and becomes "lost." According to the movement rules explained above, she will follow her remembered path, and then begin to move randomly. But because her remembered path fills her memory, she will not remember any of her additional experimentation in the maze. Her remembered path is not updated, and she travels the same incomplete path in each round. When this occurs, stasis is impossible and simulation rounds could continue indefinitely. Because of this possibility, we stop simulation for a given maze after 75 rounds. Communication among agents (explained below) makes it less likely that an agent will remain "lost" indefinitely because a "lost" agent can socially learn a new path.

Agent Communication

After all agents have solved the maze in a given round, agents may communicate about their maze solutions among three different groups of peers: neighbors, partnerships, or society. The user specifies the probability (between 0 and 100%) that each type of communication could occur randomly after each simulation round. Neighbors are mutually exclusive pairs of adjacent agents, with agents 1 and 2 forming the first neighbor pair, agents 3 and 4 forming the second, and so forth. In simulations with even numbers of agents, every agent will be part of a neighbor pair. Neighbor sharing permits only local knowledge transfer because agents never communicate outside of their fixed neighbor pair.

Partnerships are mutually exclusive collections of P_n agents, which must be 3 or more adjacent agents (we always set P_n equal to 5). Agents are assigned to partnerships with a probability of P_p which is between 0 and 100% (we always set P_p = 10%). To assign agents to partnerships, the population of agents is divided into groups of P_n adjacent agents, then each group of P_n adjacent agents becomes a partnership with probability P_p. If the number of agents is not divisible by the size of partnerships, there will be one potential partnership that is smaller than the others containing the marginal agents. Neighbor pairs and partnership groups are fixed between rounds. In all of our parameterizations, partnership sharing enables information to pass between at most two partnerships. This means that when only neighbor and partnership sharing are enabled, information can spread from any agent to at most nine other agents.

With society sharing, agents randomly selected with probability S_p communicate with one other agent randomly selected from the population of all other agents (in our main tests we always set S_p = 100%). Pairs of communicating agents in society sharing differ from neighbor pairs or partnerships because they are not stable across rounds. This is important because, while neighbor and partnership sharing permit repeated interactions and sharing of information across local networks, society sharing enables information from local networks to spread immediately to distant networks. When the user specifies more than one type of communication, communication occurs first among neighbors, next within partnerships, and across society last.

Communication rules are the same in neighbor, partnership, and society sharing. Each agent exits the maze with three pieces of information that are relevant for communication: 1) a sequence of remembered moves (M’) from which loops have been removed (up to M in length), 2) whether or not the path stored in memory describes a complete path from maze entrance to maze exit, and 3) the total number of steps taken to reach the maze exit (T, where T can be greater than M). When at least one communicating agent remembers a complete path through the maze, the agent remembering the shortest complete path explains its path (M_{min}) to all agents in the communicating group, each of whom forgets its previous path and remembers M_{min}. Similarly, when no communicating agent remembers a complete path, the agent that completed the maze with the smallest number of total steps (T_{min}) explains the path in its memory (M_{Tmin}) to all agents in the communicating group, each of whom forgets its previous path and remembers M_{Tmin}. When there are no ties (meaning only one agent remembers a path of length M_{min} or M_{Tmin}), every agent in the group remembers the same path. When there are ties, the path adopted by the communicating group is randomly selected from the set of minimum length paths. Agents remembering minimum length paths that were not randomly selected for adoption by the group retain their own remembered path. As a result, when there are ties, communication does not guarantee uniformity within a communicating group.

Results Reporting

At the end of each simulation round before agents communicate, the program calculates and reports several summary statistics on the homogeneity and efficiency of agent solutions from the round. The collected data include the number of unique paths used by agents, the number of agents using the shortcut exit, the number of agents using the minimum number of steps to reach the shortcut exit, the mean and median number of steps in remembered paths both before and after loop removal, among other things. After all simulation rounds for all 1,000 mazes for a given model parameterization are complete, the program automatically exports the results in a .txt file to a specified file location.

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TABLE 1
Summary Statistics on Path Conformity and Efficiency for the Baseline Model in the Simulation

This table presents the statistics for path conformity and efficiency for 1,000 replications of the Baseline Model for the 1st, 2nd, and final periods of the simulation. The Baseline model has the following parameter levels: Nodes = 5; Agents = 50; Memory = 20 moves; Communication = None. The minimum distance to the main exit at (N, N) is 4 steps for this size maze. The mean distance to the shortcut exit (which changes randomly with each replication) is 2.5 steps.

Path Conformity	*Period 1*	*Period 2*	*Final Period*
Average # of unique paths used by 50 agents	46.2	37.2	26.0
Path Efficiency			
Average # of 50 agents exiting at shortcut	32.9 (66%)	32.6 (65%)	32.6 (65%)
Average # agents taking fewest steps to shortcut	10.8 (33%)	12.7 (39%)	15.7 (48%)
Average mean # nodes travelled including loops	27.8	18.7	4.8
Average median # nodes travelled including loops	18.9	8.2	4.0

TABLE 2
Variable Level Perturbations Defining Alternative Conditions for the Simulation Model

This table describes the constructs we are trying to simulate in our agent-based model, the variables we have created to represent the constructs, and the levels that each variable can take in a given model condition.

CONSTRUCT	VARIABLE	ALTERNATIVE LEVELS
Social learning (Knowledge Acquisition & Dissemination)	Communication between agents (C)	(1) Zero communication (None) (2) Immediate neighbors (Limited) (3) Neighbors + Partners (Moderate) (4) Neighbors + Partners + Society (Extended)
Knowledge Retention	Number of past moves recalled (M)	(1) 20 moves (Low) (2) 100 moves (High)
Task complexity	Maze size as number of nodes (N)	(1) 5 X 5 (Simple) (2) 15 X 15 (Complex)
Population size	Population - number of agents (P)	(1) 50 (Small) (2) 500 (Large)

TABLE 3
Results from Comparisons of Alternative Models Created by Perturbing Simulation Assumptions

A: Alternative1 versus Baseline Model (1870 vs. 1850)
Baseline and *Alternative1* both use a small maze (5 X 5), a small number of agents (P = 50), and constrained memory (M = 20 moves). Alternative1 includes minimal social learning because agents' communication is limited (C = Immediate neighbors) whereas in *Baseline,* agents cannot communicate with each other (C = None). *The intent of this manipulation is to evaluate the effects of allowing communication between agents as in local societies*.

Path Conformity (Avg # paths)	*Period 1*	*Final Period*	*% Improvement*
Alternative1	46.2	14.6	68%
Baseline	46.2	26.0	44%
Efficiency (Avg % shortcut exits)			
Alternative1	66%	70%	6%
Baseline	66%	65%	-2%
Efficiency (Avg median # nodes)			
Alternative1	18.9	3.1	84%
Baseline	18.9	4.0	79%
Efficiency (Rounds to Stasis)			
Alternative1		19.0	
Baseline		10.2	

B: Alternative3 versus Alternative2 (1890 vs. 1880)
Alternative2 and Alternative3 both use a complex maze (15 X 15) and a small number of agents (P = 50). *Alternative3* includes expanded memory (M = 100 moves), and greater social learning (C = Immediate neighbors + Partners). *Alternative2* includes constrained memory (M = 20 moves), and minimal social learning (C = Immediate neighbors). *The intent of this manipulation is to evaluate the effects of improved communication and memory through partnerships when the task is complex*.

Path Conformity (Avg # paths)	*Period 1*	*Final Period*	*% Improvement*
Alternative3	49.6	24.4	49%
Alternative2	49.6	40.9	18%
Efficiency (Avg % shortcut exits)			
Alternative3	71%	75%	6%
Alternative2	71%	73%	3%

TABLE 3 (cont.)

Efficiency (Avg median # nodes)			
Alternative3	288.2	15.2	95%
Alternative2	288.2	142.3	51%
Efficiency (Rounds to Stasis)			
Alternative3		24.5	
Alternative2		75*	

C: Alternative5 versus Alternative4 (1920 vs. 1900)

Alternative4 and Alternative5 both use a complex maze (15 X 15) with large number of agents (P = 500) and expanded memory (M = 100 moves). *Alternative5* includes maximal social learning (C = Immediate neighbors + Partners + Society). *Alternative4* includes social learning that is more moderate (C = Immediate neighbors + Partners). *The intent of this manipulation is to evaluate the effects of expanded communication to the level of a society as a whole*.

Path Conformity (Avg # paths)	*Period 1*	*Final Period*	*% Improvement*
Alternative5	493.1	7.8	98%
Alternative4	493.1	211.3	57%
Efficiency (Avg % shortcut exits)			
Alternative5	71%	99%	39%
Alternative4	71%	76%	7%
Efficiency (Avg median # nodes)			
Alternative5	284.7	7.5	97%
Alternative4	284.7	14.5	95%
Efficiency (Rounds to Stasis)			
Alternative5		8.0	
Alternative4		44.0	

FIGURE 1
Concentration of the U.S Economy across Sectors
This figure plots a Herfindahl-Hirschman index-like metric of the concentration of the U.S. economy over time. Lower scores indicate greater diversity in the economy. The concentration measure is calculated by summing the squared percentage of production income of each industry (agriculture, mining, electric/gas, manufacturing, construction, transportation, trade, service, finance, other) within each year. The source data is the National Income-Realized Private Production Income by Industries (NICB) Series A 154-164 (U.S. Bureau of the Census 1949).

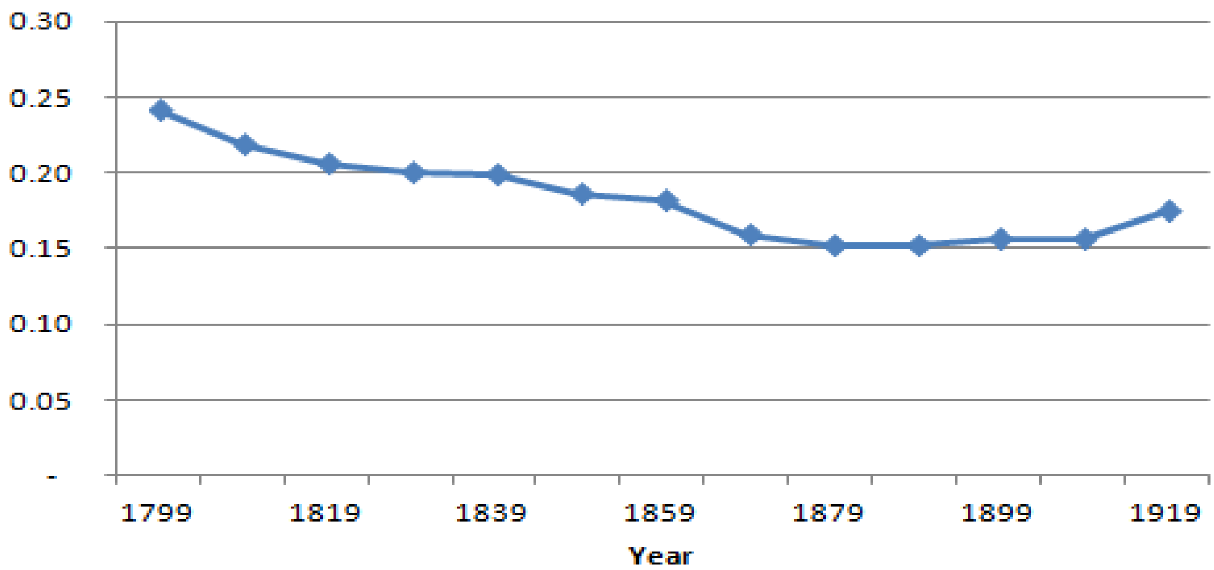

FIGURE 2
Estimate of Average Firm Size in the U.S. from 1850-1922
This figure plots an estimate of the average firm size (a proxy for business complexity) adjusted for inflation in the U.S. from 1850 to 1922. The numerator of the metric is based on national measures of reproducible assets (i.e., structures, equipment, & inventory) for non-farm/non-residential sectors of the economy, adjusted for inflation by stating amounts in 1967 dollars. The source data is the National Wealth, by Type of Asset series (Series F 426, F431, F432, F436) and Consumer Price Indexes (BLS) - all items, 1800 to 1970, Series E135 (US Bureau of Census 1949). The denominator is the number of business concerns in the U.S. economy (excluding finance, insurance, real estate, farms) sourced from the Business formations and business failures, Series E20 (US Bureau of Census 1949). The way assets were measured shifts in 1900 such that the lower 1900 point is comparable to pre-1900 figures and the higher 1900 point is comparable to the 1912 & 1922 measures.

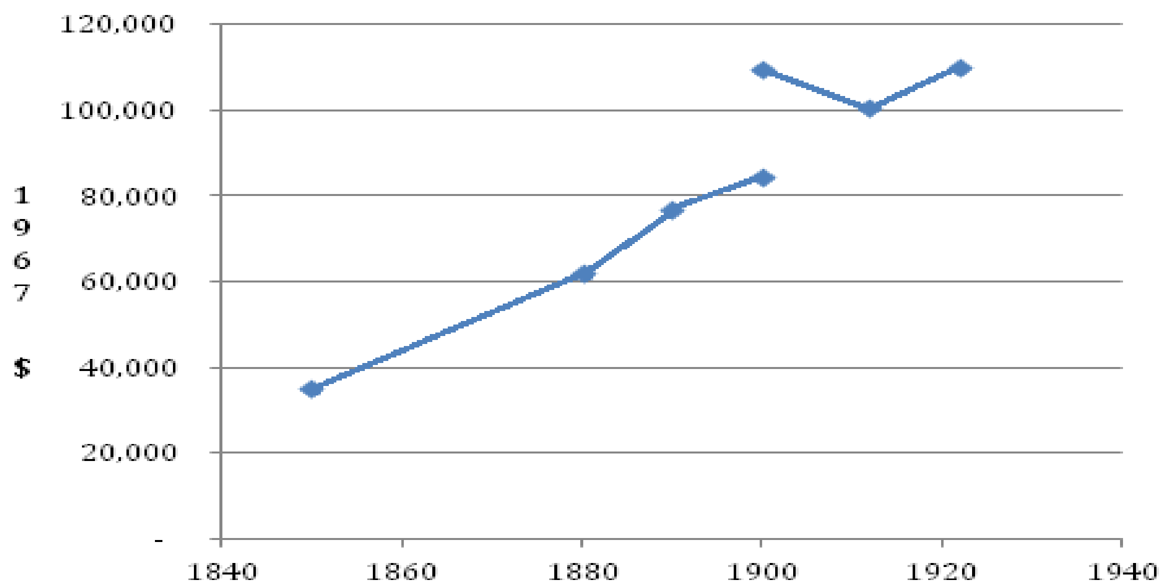

FIGURE 3
Examples of Knowledge Institutions in the U.S. Accounting Profession, 1870-1930

	Before 1890	1890s	1900s	1910s	1920s
Knowledge Acquisition	**1883** Wharton offers first sustained courses in accounting.	**1896** First exam for CPA licensing in New York State	**1902** Pennsylvania authorizes courses in theory, practice, auditing, & law.	**1917** Uniform national CPA exam offered for the first time.	
Knowledge Dissemination	**1874-89** Local societies established in New York and 12 other U.S. cities. **1883** First national accounting firm, (Barrow, Wade, Guthrie) founded.	**1890** Price Waterhouse opens affiliate (Jones and Caesar) in NYC. **1896** First CPA law in NY requires professional experience for licensure. **1897** NY Society of CPAs and Pennsylvania Institute founded	**1904** First International Congress of Accountants held in St. Louis. **1905** First issue of the *Journal of Accountancy* published. **1908-18** Classic books by Sprague, Hatfield, Montgomery, and Paton & Stevenson.	**1914** *Journal of Accountancy* begins "Student's Department" series. **1916** American Institute of Accountants, forerunner of AICPA, founded.	**1920-29** AIA Librarians produce 33 "Special Bulletins."
Knowledge Retention				**1918** AIA establishes a professional library	**1921** AIA Librarians compile the first *Accountant's Index.* **1924** First issue of *The Accountant's Handbook* published.

FIGURE 4
Number of Universities and Colleges Offering Accounting Courses from 1883 to 1926

This figure charts the number of universities and colleges that offered accounting courses for college credit from 1883 to 1926. The data sources for this figure are Allen (1927), Previts & Merino (1998, pp. 151-152), and Sampson (1960).

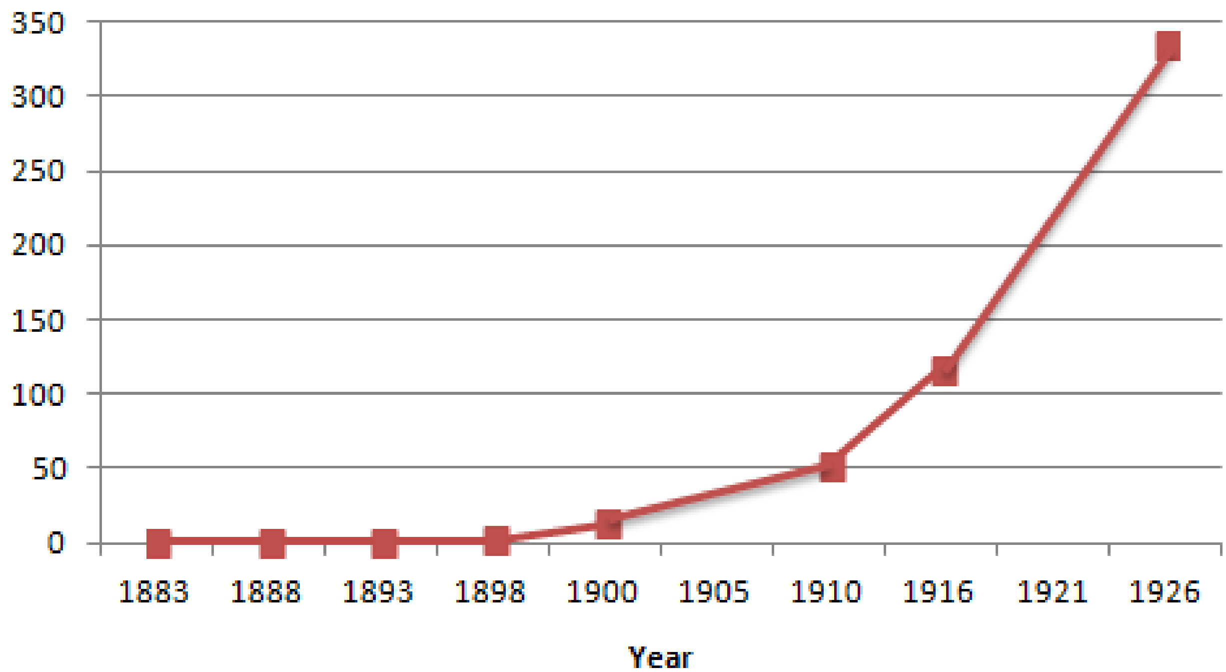

FIGURE 5
Number of Bound Works on Accounting from the 1790s to 1920s

This figure shows the number of bound works on accounting in the U.S. for each decade from the 1790s to the 1920s. The data was compiled from Bentley (1934), which resulted from research of the U.S. Library of Congress, the U.S. Copyright Office, various libraries (including several universities), the Union Catalog, and others for works on accounting published in the U.S. by those residing in the U.S. "Works on accounting is a term used to comprehend bound volumes, pamphlets, etc. devoted exclusively or primarily to an exposition of or a treatise on some one phase of accounting, such as elementary bookkeeping theory and practice, advanced bookkeeping principles and practice, subjects in advanced accounting, and accounting for some one business, profession, or service" (p. iv).

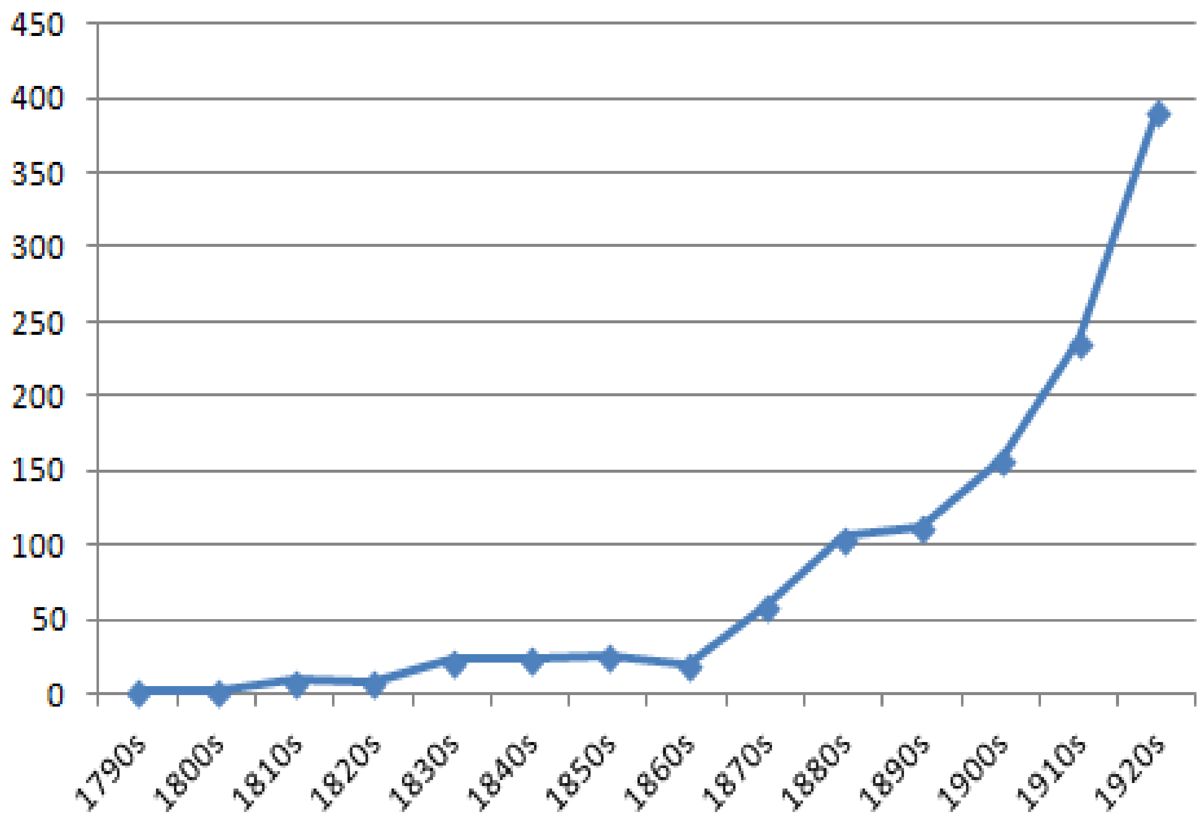

FIGURE 6
Sample 5 x 5 Maze

This figure shows a sample 5x5 maze with the entrance in the middle at Node (3,3), a regular exit at Node (5,5), and a shortcut exit at Node (3,1).

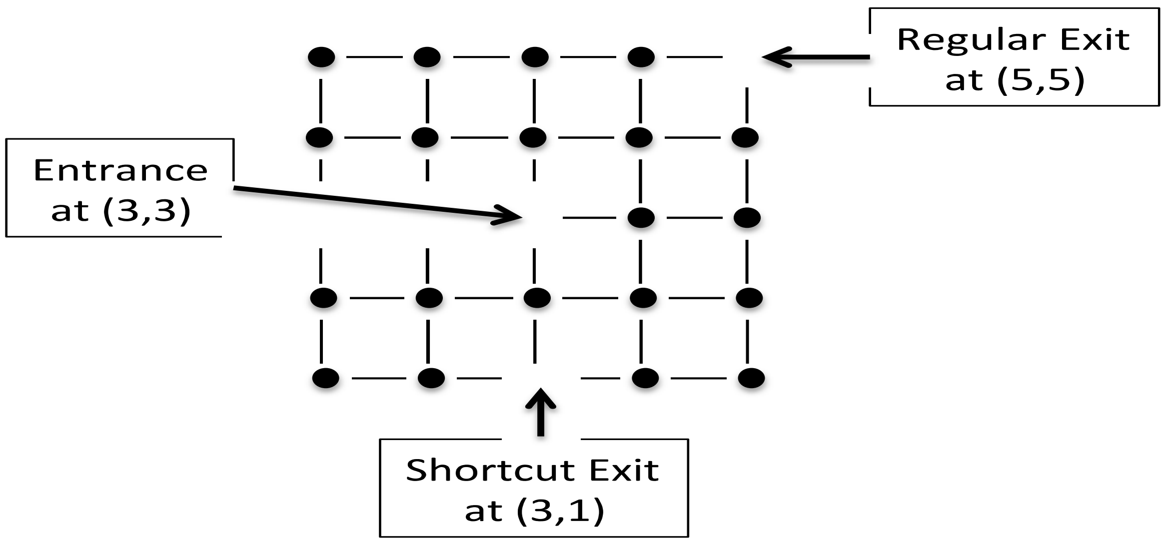

FIGURE 7
Sensitivity of Results to Levels of Society Sharing

This figure shows the results of our sensitivity analysis on the level of society sharing. We use the same parameters as the *Alternative5* model (complex maze, many agents, expanded memory, immediate neighbor sharing, partner sharing) with the only exception being the extent of society sharing. We vary the proportion of society sharing from 0 (same as *Alternative4*) to 100 (same as *Alternative5*). The primary vertical axis indexes the average number of unique paths and the secondary vertical axis indexes the average number of rounds to stasis.

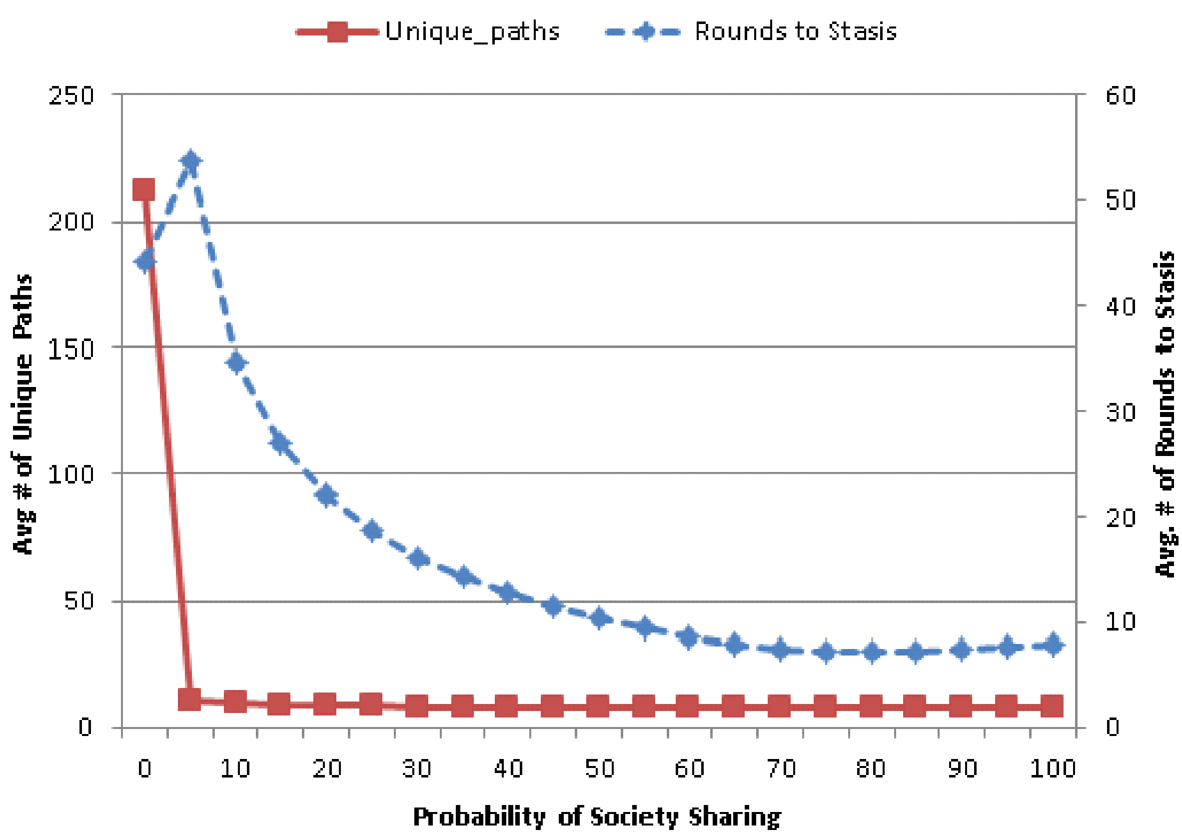

FIGURE 8
Sensitivity of Results to Errors in Communication

This figure shows the results of our sensitivity analysis on introducing various levels of errors. We use the parameters of the *Alternative5* model (complex maze, many agents, high memory, immediate neighbor sharing, partner sharing, and society sharing) with the only exception being the frequency of errors in society sharing communication. We vary the proportion of communications that have an erroneous link from 0 (the value in *Alternative5*) to 50. The primary vertical axis indexes the average number of unique paths and the secondary vertical axis indexes the average number of rounds to stasis.

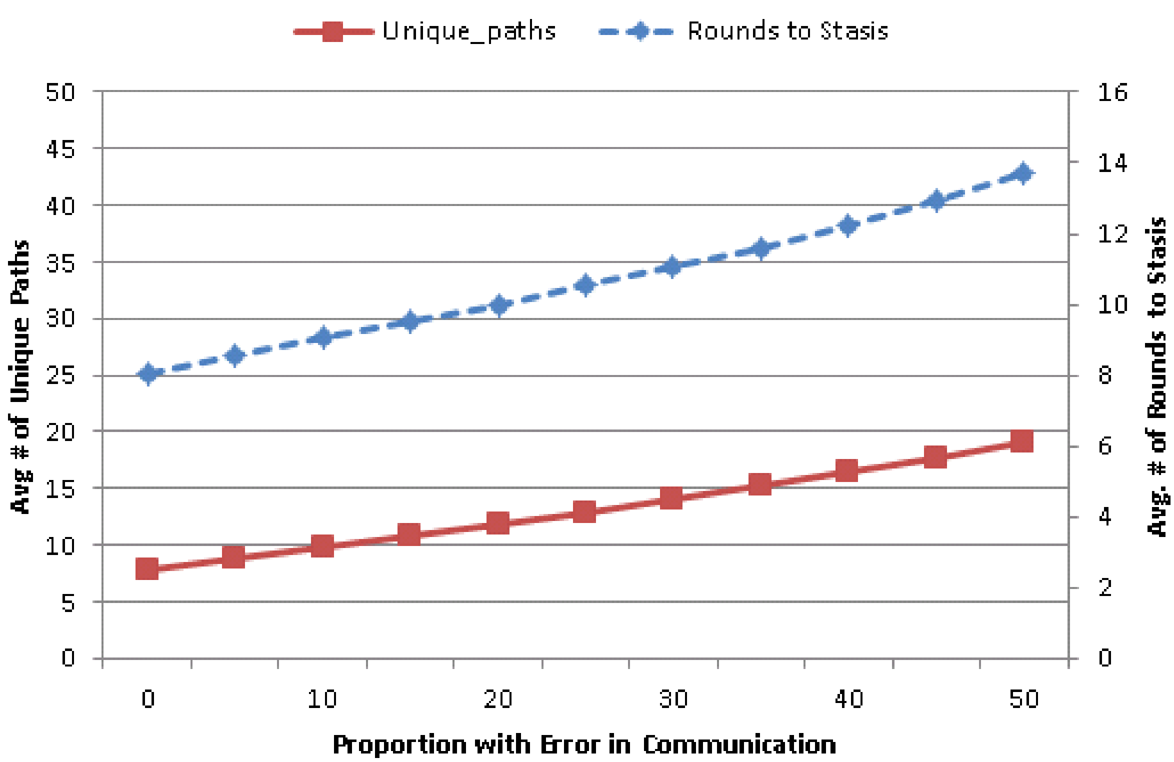

FIGURE 9
Sensitivity of Results to Levels of Agent Memory

This figure shows the results of our sensitivity analysis on the level of memory. We use the parameters of the *Alternative5* model (complex maze, many agents, immediate neighbor sharing, partner sharing, and society sharing) with the only exception being how much memory agents have. We vary the proportion of the agents with high memory (100 moves) from 0 to 100 (same as *Alternative5*). All other agents have low memory (20 moves). The primary vertical axis indexes the average number of unique paths and the secondary vertical axis indexes the average number of rounds to stasis.

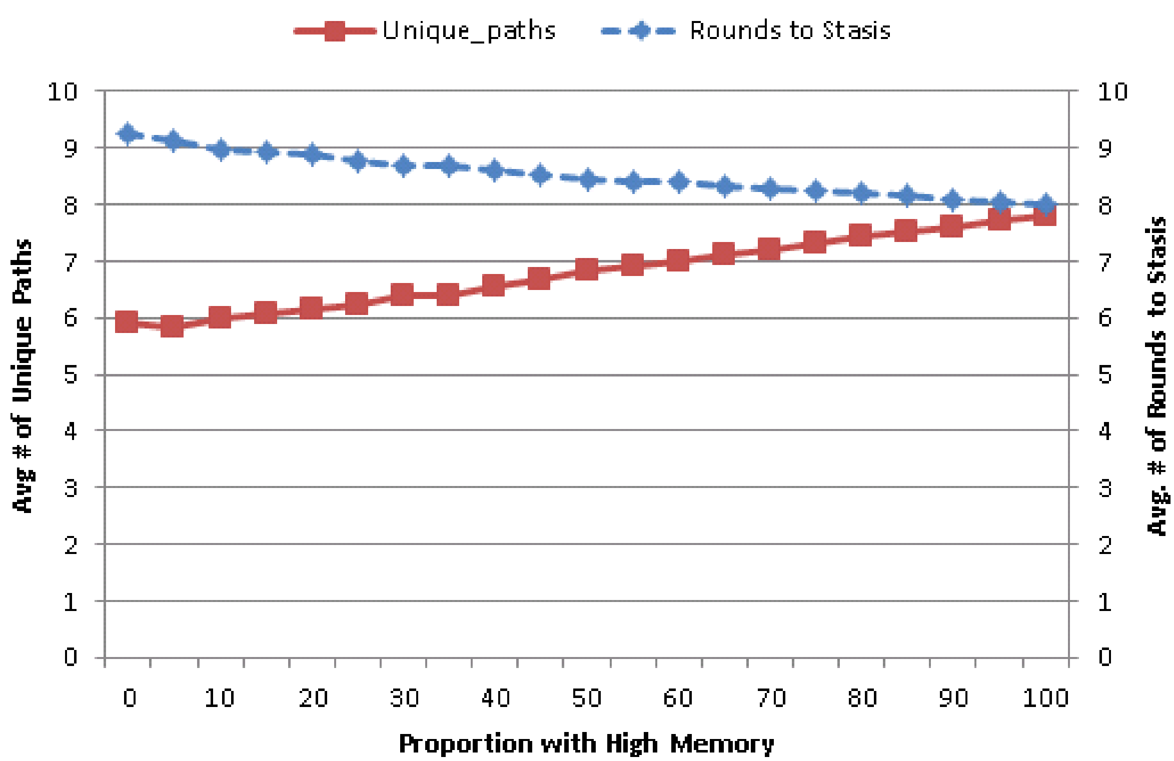

FIGURE 10
Comparison of the Sensitivity Results

This figure shows the median number of steps for each extension evaluated: the extent of society sharing, communication errors in society sharing, and how much memory agents have. The horizontal axis represents the proportion evaluated from 0 to 100 for each parameter studied. The vertical axis presents the median number of moves in the final round averaged across 1000 repetitions for each setting.