The Evolution of Double-Entry Bookkeeping

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The Evolution of Double-Entry Bookkeeping

ABSTRACT

Double-entry bookkeeping (DEB) is the foundation for the accounting systems used by profit-seeking firms worldwide. Despite DEB having existed since the early 13th century, we still do not fully understand why DEB displaced the single-entry bookkeeping (SEB) system that had existed for thousands of years. We propose answers to the four central questions needed to understand why accounting evolution favored DEB over SEB: what leads individual firms to use DEB rather than SEB (*Proximate Causation*), what survival-enhancing benefit does DEB provide better than SEB (*Ultimate Causation*), what unique feature is present in DEB but not SEB that leads to such a benefit (*Mechanism*), and why does DEB increase firms' survival prospects in uncertain economic environments (*Adaptive Value*)? Historical research suggests that multiple proximate causes can explain DEB adoption in different eras, but the ultimate cause of DEB use by profit-seeking firms is that it results in more timely and precise profit measurement than SEB. The mechanism that lies behind DEB's superiority over SEB is the DEBITS=CREDITS constraint that leads to deeper thinking about profit from operating transactions. The adaptive value of DEB comes from gradual improvements in how accountants measure profits based on a forward-looking causal focus that was less emphasized in SEB. We use our analysis of DEB evolution to suggest several areas for future research that can improve our understanding of DEB.

Keywords: double-entry, economic exchange, profit measurement, discovery process, monetary unit of account

JEL Classification: M41, D23, D83, B15

"The usefulness and power of double-entry bookkeeping is testified to by its survival since at least the 15th century and its continuing widespread use. Viewing double-entry bookkeeping this way leaves me believing that we still do not thoroughly understand why it is a powerful organizing device. I am so used to thinking of assets and the claims on them, equities and liabilities, as a way of organizing thoughts about companies that it is hard to conceive of alternatives."

Michael C. Jensen (1983, 330)

I. OVERVIEW

Institutions arise from design or evolution, or some combination thereof. The history of a designed institution can be reconstructed from written documents (e.g., patent applications, minutes of committee meetings, etc.) or interviews with those involved in an institution's early history. An example of a designed accounting institution is the Financial Accounting Standards Board (FASB), whose institutional origins have been documented extensively (e.g., Zeff, 2015, 2016). Understanding what FASB's designers sought to accomplish and how FASB standards affect investors and other groups, while difficult to measure, can be identified using available data.

The most widely known, but least understood, evolved accounting institution is double-entry bookkeeping (DEB), which dates back to at least the early 13th century. While no firms that we know of used DEB before then, today all but the smallest profit-seeking firms use DEB. The near universal adoption of DEB could occur either because: (1) business managers and their accountants chose DEB because they deemed it superior to the alternative of single-entry bookkeeping (SEB), (2) the choice between DEB and SEB is immaterial or unimportant (i.e., DEB is a neutral mutation)[1] and DEB's use became merely customary, or (3) DEB offered survival advantages over SEB in managing a business even though no manager or accounting scholar has fully explained why. We explore this third possibility focusing on why and how DEB has adaptive value for profit-seeking firms.

[1] Miller (1977) discusses neutral mutations in the context of corporate debt. Within accounting, Yamey (1964) argues that DEB offers no apparent advantages over SEB and that DEB has been institutionalized because academic coursework is based on DEB, while SEB has slowly disappeared from the curriculum.

Evolved institutions are analogous to evolved biological traits in that a change over time due to natural selection can be impossible to chronicle because evidence of failed innovations does not survive sometimes – i.e., the fossil (or documentary) record is incomplete. It is thus tempting to search for "missing links" to fill an evolutionary record as happened in debates that followed the publication of Darwin (1871). Making sense of fossil evidence was systematized when Tinbergen (1963) identified four questions to be answered about any entity that evolved.[2]

We apply Tinbergen's (1963) four questions to double-entry bookkeeping with the goal of developing an agenda for future research on DEB (see Table 1):

1. *Proximate Causation*: What leads an individual firm to use DEB rather than SEB as the foundation for their accounting system?
2. *Ultimate Causation*: What survival-enhancing benefit does DEB provide better than SEB?
3. *Mechanism*: What unique feature is present in DEB but not SEB that leads to such a benefit?
4. *Adaptive Value*: Why does DEB increase firms' survival prospects in uncertain economic environments?

The available historical evidence suggests that no single *proximate cause* has consistently spurred use of DEB over SEB in different times and places. Early on, DEB improved recordkeeping for large complex banks (Sangster 2016) and retail merchants (Lee 1973, 1977). Subsequently, DEB use was justified on moral grounds as a basis for more prudent management (Pacioli 1494) – e.g., DEB later aided cost measurement and management (Garner 1954/1976). As DEB use became more common, firms mimicked other successful organizations – e.g., Andrew Carnegie did this in the late 1800s (Carnegie 1920, 36). In short, several proximate causes have influenced DEB's adoption in different times and places.

While no single proximate cause is evident in DEB's history, one clue to DEB's ultimate causation is its widespread use by for-profit firms. We hypothesize that the *ultimate cause* (i.e., the main benefit) of DEB over SEB for a modern profit-seeking firm is that it results in more timely and precise income

[2] See Bateson and Laland (2013), Nesse (2013), and Wilson (2017, 5-6), among others, for further elaboration on Tinbergen's Four Questions.

measurement than SEB. Realized profit is crucial to the survival of businesses (Alchian 1950) and net resource inflows are likewise crucial for the survival of nonprofits and governments. SEB, as implemented before DEB's appearance, recorded only asset and liability quantity changes due to specific transactions and typically delayed consideration of profit until closing the books at the end of an accounting period. We hypothesize that these features of SEB hindered timely and accurate profit measurement whereas DEB measured changes in monetary values more continually. Thus, even when a decision-maker knows nothing about how or why DEB use could increase the firm's profitability over what it would have earned using SEB, a firm can realize higher profits if DEB is used rather than SEB.

The *mechanism* that leads to improvement in firms' profitability and survival prospects is the DEBITS=CREDITS constraint that is ever present in DEB but lacking in SEB. In the short run, DEB helps firms avoid unfair trades because the journal entries would not balance otherwise (Basu 2015). In the long run, we hypothesize that decision-makers who regularly grapple with DEB-based transaction analysis learn to think more deeply about complex transactions that entail risky future cash flows and uncertain performance obligations. The result is that learning from repeated DEB-based transaction analysis improves accounting and business knowledge in the long run because it leads a decision-maker to think harder about why a firm's products are profitable. We suggest that the fundamentally different questions posed by DEB accountants in transaction analysis lie at the core of modern accounting theory on income recognition – i.e., when is the earnings process complete and has the firm received valuable consideration from the buyer?

The *adaptive significance* of DEB comes from gradual improvements in how accountants measured profits and increased their forward-looking focus. This let DEB profit data assume a greater role in predicting future profits from both existing and potential new products. That is, DEB's adaptive significance is that it gradually allowed business executives to more accurately identify which products were profitable and which were not.

Two caveats are warranted before proceeding. First, we theorize DEB as an evolved profit discovery tool that resulted from a hard-to-observe evolutionary process and requires future empirical work to validate. Our paper focuses more on getting the questions right than on figuring out the answers. Thus, we caution against inferences that our paper supports any single functional explanation for why DEB evolved as it did given possible discoveries of new historical evidence. Second, our analysis does not negate the value of historical research on DEB's use in different settings. However, historical analysis often focuses on identifiable actions by specific human actors in a short time and does not directly address issues pertaining to the long-run evolution of institutions. Our evolutionary perspective complements existing historical research in providing a more complete understanding of why DEB has been an important economic institution.

The next section describes what historical research says about DEB's proximate causation. The following sections address DEB's ultimate causation, mechanism, and adaptive significance, respectively. Each section on a specific question offers suggestions for future empirical research. Concluding remarks are provided in a final section.

II. PROXIMATE CAUSATION

We first explore DEB's proximate causation. Historical research tells us something about the observable actions and possible motivations of early DEB adopters. We review some historical research on how DEB came to be used in different times and places. We then discuss avenues for future research on DEB's proximate causes.

The earliest known accounting artifacts are the clay tokens used to record transactions in Mesopotamia (now Iraq) circa 8,000 BCE (Schmandt-Besserat 1992a; 1992b).[3] These tokens represented

[3] Early recordkeeping systems are studied in Mattessich (2000), Basu and Waymire (2006), Basu, Dickhaut, Hecht, Towry and Waymire (2009), Basu, Kirk and Waymire (2009) and related papers, while the period before known transaction records is surveyed in Brown and Palmrose (2005), Sy and Tinker (2006), Basu (2015) and others.

physical quantities of cultivated grain and abstract labor units, enabling agricultural cooperation. These records extended planning horizons since farming takes months compared to the daily food-gathering plans of nomadic hunter-gatherers. Settling down let farmers amass property and livestock that likely led to a shift from sharing within kin groups to trading between relative strangers (Sahlins 1972). A system of *bullae* or clay balls encasing tokens emerged (c. 3200 BCE) to record the identities of transacting parties using personal seals (Schmandt-Besserat 1992b), which enabled multi-period contracts where performance tracking mattered. These multi-period contracts were the impetus for the cumulative records of transactions that we now call bookkeeping.

While extensive SEB systems could be used to monitor the activities of thousands of workers (Grier 1932; Farag 2009), it was still difficult to assess wealth changes by adding up different physical units within such a system (Mickwitz 1937). SEB systems date back thousands of years and were invented and used by many civilizations including Italy before DEB. Thus, large organizations existed and thrived using SEB (Yamey 1949; Jack 1966). However, a SEB system lets net assets and periodic profit be determined only after all units are converted into money terms (Childs 1895, 24). That is, SEB records transactions focusing on observed movements in asset quantities involving parties to the transaction.

The primary function of Italian accounting before DEB was to track debt obligations where the firm was either a borrower or lender, and the books could serve as evidence in legal proceedings (de Roover 1938; Yamey 1949; Martinelli 1974; Sangster 2016). Keeping track of financial obligations would have been important since a reputation for timely repayment of loans by borrowers and accurate records of outstanding loans by lenders was necessary for large scale credit markets to be sustained.

Lee (1973) pinpoints DEB's earliest known use to a Florentine bank in 1211 CE. These banks developed DEB to create more reliable records for loans that could be audited more effectively (Sangster 2016, 308-10). DEB was advantageous because it was easier to identify both the issuance of a loan and later repayments in a single account or via cross-references to multiple accounts. Thus, DEB

more accurately tracked account balances over multiple periods, which could be important in a legal dispute about the existence and current balance of a loan made by a banker.[4]

Cotrugli (1458/2017, Part 1, Ch. XIII) advocated that a "merchant" (a businessman of high character and ability) use DEB for prudent management. Pacioli (1494, chapter 1) notes that using DEB is a good business practice because it helped merchants "keep all their accounts and books in an orderly way," and that being a "good bookkeeper and ready mathematician" lets a merchant's mind be untroubled. Cotrugli and Pacioli extolled the prudent use of DEB as it helped firms sustain a reputation for honest conduct and gain access to future debt financing. Prudent management is consistent with a deeper human aversion to losses (Kahneman and Tversky 1979), the longstanding accounting principle of Conservatism (Basu 1997), and the asymmetric processing of gains and losses by the human brain (Breiter et al. 2001; Knutson et al. 2001; Tom et al. 2007; Li et al. 2017).

Proximate causes of DEB adoption would likely have been reinforced by some firms imitating DEB use by other prominent firms – e.g., Andrew Carnegie adopted DEB for Carnegie Steel because "all the great firms kept their books in double entry" (Carnegie 1920, 36). Increased availability of educational resources would have similar effects; merchants could more readily learn DEB as Italian *abaco* schools and textbooks made DEB knowledge more accessible.

In combination, several factors likely helped DEB become a predominant business practice.[5] Effective use of DEB requires a conducive business environment, which includes the broad acceptance of virtuous and prudent profit seeking by entrepreneurs (McCloskey 2016). If these conditions are met,

[4] Sangster (2016, 310-11) observes that the Italian courts came to recognize DEB as acceptable evidence, and DEB then gained broader acceptance as merchants adopted it.

[5] Rogers (2003) notes that four main forces affect the extent and speed with which an innovation is diffused: the nature of the idea constituting the innovation, the quality of communication channels between members of a population, length of time available to learn about and implement the innovation, and the structure of the social system that will use the innovation.

along with the availability of money, arithmetic, writing, and other needed institutions (Littleton 1927), then DEB could become used more widely as firms expanded in scale and scope.

Additional research is needed to better understand how a firm decides to use DEB rather than SEB. A starting point might be to ask ChatGPT: "When should I implement a double-entry bookkeeping system in my company?" Most firms likely start out using SEB and only later adopt DEB. When does this occur – is it once the firm has "growing pains"? Is DEB adopted when a firm learns of a near-term sales increase? Or when the entrepreneur approaches a bank for a loan? How costly is it to adapt a SEB system to a DEB one? What happens after a switch from SEB to DEB? Do firms switching to DEB have a "big bang" expansion in their chart of accounts, or does this emerge incrementally?

Contrarily, do any firms consider DEB but stick with SEB? If so, why do they choose SEB? Is it a decision to retrofit the existing SEB accounting system to do the same things that DEB does? If so, which functions of the SEB accounting system improved after such a retrofitting?

This research could be extended to study both the demand and supply sides of the market for bookkeeping services. What kinds of firms seek bookkeeping services – are they profitable or are they losing money and need help in reorganizing? What determines whether a firm does its bookkeeping in-house or outsources it? If done in-house, what backgrounds are sought of bookkeepers? What professional training is needed – e.g., when does a company hire a CPA to oversee its accounting? If bookkeeping is initially outsourced, when and under what conditions is it internalized? Surveys could be conducted of entrepreneurs who have adopted DEB and the consultants who help design and implement DEB systems. Examples of a similar approach are Allee and Yohn (2009) and Cassar (2009).

III. ULTIMATE CAUSATION

We now lay out our argument that DEB's ultimate causation is differences in profit measurement between DEB and SEB. We first describe how natural selection differs from intentional

choice and then how DEB differs from SEB in terms of profit measurement. We provide a brief historical overview of DEB-based profit measurement and close with suggestions for future empirical research on DEB's ultimate causation.

DEB evolution reflects changes in the propensity of firms within the overall population to use DEB instead of SEB. Any change in the frequency of DEB use reflects the combined effect of choices by individual managers *and* selection by the environment of which firms survive. Intentional choice of DEB can favorably affect survival prospects *if* actors are highly knowledgeable about how their choice of DEB will affect the firm's survival in risky environments. While much procedural knowledge about how to implement DEB has existed for centuries, conceptual knowledge about why DEB use is desirable has been in short supply. That is, merchants may be driven by various proximate causes to use DEB, but such choices are not likely rooted in any clear understanding that a firm is better off using DEB than SEB. For this reason, we believe that changes in DEB use over time have been more the result of selection than purposeful choice.

Wilson (2019, 18) notes that natural selection occurs by testing new alternatives' *survival properties* in a specific environment. He summarizes how a biological trait evolves as, "mutation proposes, the environment disposes." Cultural innovations face the same selection forces as biological traits (Campbell 1960; Dawkins 1976; Richerson and Boyd 2005). In competitive environments, realized profits enable survival while realized losses eventually lead to business failure (Alchian 1950). We argue that the advantage of DEB over SEB results from its better ability to measure profits in a timely and accurate fashion. That is, we suggest that SEB firms were more likely to perish than DEB firms as business environments became more complex.

For this argument to be valid, DEB must measure profit differently than SEB. For present purposes, SEB is an accounting system where individual account changes due to a transaction are viewed independently – e.g., a credit sale of a single inventory unit to a customer for $200 would let the

receivable be recorded without reference to the inventory reduction of one unit. Thus, an SEB bookkeeper would record changes in Receivables and Inventory separately in their physical units without requiring that they even be valued in money units:

RECEIVABLES +200
INVENTORY –1

In short, an SEB accountant focuses on changes in balance sheet quantities associated with a specific transaction and does not reckon profit until the books are closed at some future date.

In contrast, a DEB system meets three conditions (Zerbi 1952, as listed in de Roover 1955): (a) each transaction is recorded twice with dual effects captured by equal debits and credits (Martinelli 1974, 217), (b) the firm's chart of accounts includes a "set of accounts opened to expenses and revenues, the so-called 'income accounts'" in addition to the permanent accounts for assets and liabilities already present under SEB (Martinelli 1974, 220), and (c) the debit and credit side of the entry are linked by cross-reference or recorded so that the location of the other side of the entry is obvious by how it is recorded (Martinelli 1974, 271).[6]

Nowadays the credit sale of one inventory unit for $200 would be recorded under DEB using a perpetual inventory system with the item's original cost (COST) representing an expense:[7]

RECEIVABLES	200	
SALES REVENUE		200
COST OF SALES	COST	
INVENTORY		COST

The result is that DEB entries often depend to a greater degree on past events and future contingencies. In this example, recording the cost of inventory sold under DEB involves reference to both current and

[6] Although Zerbi (1950) viewed the third criterion as essential, Melis (1950) and de Roover (1955, 411) disagreed, arguing that sometimes books were cleverly structured to make cross-referencing entries redundant.
[7] It is important to point out that these entries do not reflect ones made in historically adjacent periods. The former SEB entry is similar to what would have been entered before the appearance of DEB whereas the second entry more closely resembles the entry to record a sale as a student would learn it today. Thus, we caution the reader that we are referring to differences between SEB as practiced several centuries ago and DEB today.

prior transactions involving the manufacture or purchase of inventory as well as the probability that the receivable will be collected.

Historical evidence suggests that DEB offered an easier means for business owners to calculate profit than SEB. Pacioli (1494/1914, chapter 20) notes how DEB is useful because accounts can separate out entries of "the highest importance in commerce" where "*without entering the value of the things that you have traded*, you could not, from your books and accounts, learn, except with great difficulty, what your profit or loss is."[8] Cotrugli (1458/2017, 59-61) advised merchants to be "clever in seeking business, weigh up opportunities and find new ones, for the proof of an active intelligence is finding new things" and to "know the right moment to switch merchandise, when he sees that profits are diminishing because a sector is becoming crowded." Stevin (1607) likewise stressed the importance of profit data by product type (Yamey 2000, 4-5). Cross-referencing of entries creates linkages within and across transactions that can help an entrepreneur use past data to identify how much more profitable one type of transaction is than another and adapt business decisions accordingly.[9]

The surviving records for Rinieri Fini & Brothers (1296-1305) and Giovanni Farolfi (1299-1300), Florentine firms operating in France, suggest that many key elements of DEB were in place by the late 13th century (Lee 1973, 1977). The surviving "General Ledger" of the Giovanni Farolfi branch in Salon contains debit (credit) accounts in the first (second) half of the book, and includes references to an earlier White Ledger, a Red Book for the main merchandise accounts, a Cloth Ledger for cloth goods, an

[8] Thompson (1777, book II, chapter I) reinforces this point when he remarks that accounts categorized by product type can provide useful data: "Book-keeping by Double Entry…. is the art of keeping our accompts in such a manner, as will not only exhibit to us our net gain or loss upon the whole, *but our particular gain or loss upon each article we deal in, by which we are instructed what branches to pursue, and which to decline*; a piece of knowledge so very essential to every man in business, that without it a person can only be said to deal at random, or at best can be called but guess'd work." (emphasis added)

[9] We argue that DEB makes it easier to measure product-specific profits, not that such measurement is impossible with SEB. Some firms did track product-specific profit data with a SEB system. For example, Yamey (2000) names a few merchants starting in the late 1300s (long after DEB was introduced) who kept SEB accounts for different goods in both quantities and values, and later calculated and recorded gross profits for these goods when an inventory had been fully sold or when a venture was dissolved. However, even in these advanced SEB systems competing with rudimentary DEB systems, gross profit was only calculated periodically rather than perpetually.

Expense Book, and a Cash Book (Lee 1977). This inter-related set of books contains many distinct merchandise inventory accounts and separate accounts for many trading partners, showing that the company classified its transactions using a large chart of accounts, and accumulated its net positions periodically in a trial balance. While these inventory accounts did not lead to profit reckoning after each transaction, they allowed more timely profit reckoning as inventory batches were exhausted (Lane 1945). The surviving ledger reflects an understanding of the algebraic opposition of debits and credits, single accounting monetary unit, accounting period, proprietor's equity as the net of assets and liabilities, and profit or loss as the net change in equity during an accounting period (Lee 1977, 85).

Other examples reflecting a more advanced emphasis on profit measurement include the "venture accounting" used by 14th century Venetians and 16th century British firms that tracked profit from individual trading voyages (Pacioli 1494/1914, ch. 20; Winjum 1970; 1971). More generally, we suggest that the use of DEB as a profit measurement tool likely accelerated as firms grew dramatically in size during the Industrial Revolution in the 18th and 19th centuries (Garcke and Fells 1889; Johnson and Kaplan 1987). Garner (1954/1976, 25) notes that the rudimentary Italian cost accounting techniques "gave impetus to the early growth of double entry bookkeeping by showing its adaptability to new and different situations." This was, in part, a contributing factor behind the "relationship between the growth of bookkeeping and capitalism" (Garner 1954/1976, 17).

Medieval manufacturing was based on a "putting-out" system where each stage of production was done by specialized workers, who were paid on a piece-rate basis but bore the costs of their tools and workspace (e.g., de Roover 1941, 9-10). Job costing records appeared in Tuscany as early as 1397 (Melis 1950, 558-560). The scientific revolution led to better water mills, and later water-powered mass manufacturing led to industrial production being centralized in factories with the manufacturer incurring the costs of machinery and large buildings. These fixed manufacturing costs were allocated to inventory through standard costing systems that developed rapidly after the 1700s (Fleischman and Tyson, 1998).

Garner (1954/1976, 30) describes the gradual evolution of cost accounting, which took place mainly within firms and was not publicized or published to maintain competitive advantage:

> "(T)he whole development of accounting has been a very gradual process – *natura non facit saltum* – and cost accounting has been no exception. One cost accountant or bookkeeper passed on his methods to another for experiment and trial rather than writing textbooks or learned articles…. (I)t should be noted that perhaps another reason why so little was written on cost accounting before 1855 was the traditional attitude of business men towards divulging any comparative advantages in manufacturing techniques to possible competitors. The handling of a firm's accounts in an especially advantageous way was considered personal, a secret not to be let out to rival firms." (*Latin* in original).

The need for accurate cost data became apparent as organizations grew larger. The experience of mid-19th century U.S. railroads illustrates this (Chandler 1977, 103-120). Railroad managers' efforts to refine accounting measurement in managing their firms "brought a revolution that contributed to the emergence of accounting out of bookkeeping. The techniques of Italian double-entry bookkeeping generated the data needed, but these data, required in far larger quantities and in more systematic form, were then subjected to types of analysis that were new" (Chandler 1977, 109). DEB-based data and related analytical techniques led to aggregation of cost accounts into different categories that varied with volume and could be condensed into an "operating ratio" that evaluated operating expenses as a percentage of net sales for different railway lines and services. Bliss (1924) describes the use of accounting data by early 20th century managers in several industries in considerable depth.

Future business decisions can be affected by the original cost classification scheme. Littleton (1953, 122) remarks that because of "standard cost methods fitted into the double-entry type of account-categories, we have in the result a convincing demonstration of the amazing adaptability of the scheme of classifying data that took form in its essential features, five centuries ago." In evolutionary terms, DEB adapted to mass manufacturing environments to add value by better identifying unit costs to match against sales and later to control costs by reducing inefficiency (Fleischman and Tyson, 1998).

Historical research suggests that complete income statements were not typically produced by organizations before 1800 (Yamey 1949; 1964). While the move to producing complete income

statements is historically important, it only extends income measurement for a single transaction to a transaction set that can include many transactions, as is the case for modern corporations. In both cases, DEB provides an integrated measure of profit that links financial performance for a period with financial position. Littleton and Zimmerman (1962, 47) illustrate this when they suggest that DEB makes "quantitatively visible the inescapable and natural interrelation of enterprise income and enterprise capital," which can be obtained by either "*examining the ledger accounts or by reading financial statements*." (*emphasis* added)

Even though no single theoretical explanation for why DEB has displaced SEB exists, some accounting scholars suggest that income measurement is the central function of evolved DEB (Littleton 1953; Ijiri 1975). An emphasis on profit measurement is also consistent with the work of Werner Sombart (1902), who hypothesized that DEB promoted capitalism by encouraging an entrepreneurial mindset where "profit becomes an end which dominates the whole system" (Parsons 1928, 649) – see also Most (1972; 1973).[10] Modern scholars group these claims together under the heading of "Sombart's Hypothesis," in honor of its first proponent (Yamey 1949; Most 1972). Still, one nagging question challenges the validity of Sombart's Hypothesis: if DEB's main value comes from measuring income, why did it take several hundred years before companies began producing firm-wide income statements (Yamey 1949; 1964)?

Our hypothesis is that DEB is a tool used by managers who had limited causal knowledge of the ultimate forces behind DEB's displacement of SEB – i.e., managers' ability to recognize the effects of DEB use or to predict future DEB improvements was minimal. Accounting practice at any given date is path-

[10] Like Sombart, Max Weber argued, according to Carruthers and Espeland (1991, 32): "Rational capital accounting, in conjunction with calculable law, rational technology (mechanization), free labor, and the commercialization of economic life, is, for Weber, an element in a general process of rationalization that is both a precursor to and the consequence of modern capitalism." Schumpeter (1950, 123) said that DEB was a "towering monument" of capitalism that turned "the unit of money into a tool of rational cost-profit calculations." Mises (1949, 231) suggested that DEB "makes success and failure, profit and loss ascertainable."

dependent and is updated if a firm's accounting system (i.e., DEB versus SEB) is correlated with future survival-enhancing operating decisions. That is, causation in evolutionary terms is determined by whether DEB use improves a firm's long-run survival prospects rather than DEB's short-term proximate effects (e.g., better organized recordkeeping) that may have led managers to adopt DEB over SEB in the first place.

Why larger, more complex firms ultimately chose DEB is that economic competition "selects for" firms with positive profits (Byrne 1937, Alchian 1950). Quicker and more accurate profit evaluation under DEB than SEB can better guide decisions about the scale and scope of firms in dynamic business environments (Littleton 1933; Ijiri 1981).[11] As DEB use evolved in complexity, it let entrepreneurs more easily compare transaction outcomes across products and over time using a common monetary yardstick, which helped them both better see where they had earned greater past profits and, far more importantly, better predict how they could earn greater future profits. In this way, quicker profit measurement and analysis using DEB ensures that "fuller use will be made of the existing knowledge" by the firm in identifying future profit opportunities (Hayek 1945, 521).

To summarize this section, we have described how DEB was slowly adapted over the course of several centuries to provide increasingly finer measurement of profit and its components. Several issues come to mind and can guide future empirical research on DEB evolution. Researchers should explore how DEB firms estimate profits before and after DEB is first adopted. Does DEB adoption lead firms to disaggregate transactional data more finely after they switch? How soon after the switch to DEB does this occur? How often do managers review product and customer profitability after DEB introduction?

[11] Adam Smith (1776, Book 4, Chapter 2) notes that "it is only for the sake of profit that any man employs a capital in the support of industry" and Deirdre McCloskey (2016, 94) defines capitalism as "trade-tested betterment… governed by profit."

IV. MECHANISM

We hypothesize that entrepreneurs using DEB could eventually measure profit from individual transactions better, which led them to ultimately learn more about (i.e., "discover") opportunities for profitable future exchanges. The definition of wealth as a residual claim capturing the difference between assets and debts measured in a single monetary unit of account, later supplemented with income accounts, likely reflected how entrepreneurs came to view their business activities. Russell and Whitehead (1910, 11-12) argue that definitions are crucial because they (a) point to something important worth understanding, and (b) often analyze a common idea from a different perspective, making definite what had previously been vague and thus sharpening knowledge.

Once ownership wealth was defined clearly and measured more precisely with DEB in a single monetary unit of account, merchants could focus on increasing this wealth metric. Since most Italian businesses were family enterprises, this new definition of equity likely spurred a separation of previously commingled personal and business accounts and facilitated partnership arrangements.[12] While profit and wealth concepts existed under SEB, DEB likely enabled more continuous profit tracking and measurement of profit by product type, and facilitated comparison of product types, trading partners, retail locations, etc., because profit was measured in a single monetary unit.

We hypothesize that use of DEB was accompanied by a shift in how exchange transactions were mentally evaluated. The use of DEB surfaces a demand for accounting conceptual knowledge, which we describe first. We then discuss how DEB improves feedback from product markets to business decisions and can alter the mental frameworks of decision makers using DEB data.

When a buyer pays $20 for an economic good, she expects to be at least as well off as she would by keeping the $20 and not buying the good. Hence, her increase in goods and reduction in cash are

[12] These arguments are part of Sombart's Hypothesis (Yamey 1949, 99-100), although usually applied to DEB in eras after firms were regularly producing income statements.

causally linked. DEB reflects this causation by simultaneously linking the increase in goods with the decrease in cash as equal valued debits and credits in a journal entry.

Ijiri (1975, 84) explains how DEBITS=CREDITS leads a DEB accountant to see a transaction differently than his SEB counterpart:

> "(D)ouble-entry can enormously affect our perception of economic events. Under the so-called single-entry system, a cashier can keep his record quite independently from a warehouse bookkeeper who records inventory and inventory changes. But an accountant who is trained in double-entry bookkeeping cannot treat a decrease in cash or an increase in inventories independent of each other. A decrease in cash cannot be recorded unless he finds a proper debit account. In doing so, he is led to recognize the cause-and-effect relationship of changes in resources. *Eventually, he acquires the habit of always looking at a change in relation to other changes rather than in isolation*." (*emphasis* added)

The last sentence highlights the major change from using arithmetic in SEB to count and record what comes in or goes out separately to an algebraic perspective in DEB that imposes a mathematical constraint that must always balance, so that changing any account requires a simultaneous offsetting change.[13] Algebra is much harder than arithmetic, which likely explains why many first-time accounting students find DEB difficult and counterintuitive.

Schelling (1995) suggests that the DEBITS=CREDITS equation is not obvious *ex ante* but with careful definition seems obvious *ex post* (see also Jensen 1983, 330). But why does DEBITS=CREDITS make *economic sense* rather than being a mere algebraic identity or tautology? Basu (2015, 256) argues that DEBITS=CREDITS is a corollary of The Law of Conservation of Exchange Value, which is that "arm's-length transactions in perfect and complete markets do not create or destroy value," because arbitrage forces equal-valued exchanges. Since medieval markets were imperfect, some other mechanism could

[13] Ellerman (2014, 483) analyzes DEB mathematically and observes that DEB is a "group of differences using pairs of unsigned numbers ('T-accounts')." DEB can be applied using a vector of different physical units instead of a single monetary unit (i.e., vector algebra), but apples and oranges will remain incommensurate so wealth changes will be difficult to discern. The vector of physical units can be multiplied by a price vector to create a scalar quantity to ease comparison, which is what DEB does for each transaction, but SEB did only when ventures were liquidated and accounts were closed. Although DEB imposes an additive identity in the scalar values, it is also a multiplicative identity in the underlying prices and quantities, which makes it more informative.

have led to equal-valued exchanges being observed routinely. In medieval Italy, religious prohibitions on usury encouraged an emphasis on "just" exchanges, where both sides received equal values based on prevailing market prices, even in barter transactions. Regardless of its proximate causes, DEB use led to more careful thinking about the residual difference between asset values in recording exchange transactions.

Transaction analysis is complex under DEB because implementing DEBITS=CREDITS raises valuation issues. If an entrepreneur purchases a bundle of two assets (e.g., land and building) for cash of $100,000, how should the transaction be recorded? Suppose that independent appraisers value the land and building at $50,000 and $75,000, respectively. Should these two amounts be recorded with a credit to owner's equity to balance the entry? If a gain on purchase is not permitted, which of the three values should be adjusted to make the debits and credits balance, and why?

Income statement accounts introduce new questions about profit measurement and future contingencies. What is the value of inventory made by the seller? Is there hard evidence that a sale is at arm's length? What should be the carrying value of a damaged asset? Can sales revenue be recognized when the seller has performed some, but not all, of the contracted tasks? How should the costs borne in anticipation of a future sales transaction be recorded? Accountants still grapple with these questions that underlie the *Historical Cost*, *Objectivity*, *Conservatism*, *Revenue Recognition*, and *Matching* principles that emerged from accounting practice over several centuries (Littleton 1933; Gilman 1939; Paton and Littleton 1940; Chatfield 1974). These questions all tie back to profit calculation at the exchange, product, and/or the firm level, but first arise when recording a journal entry under DEB.

DEB causes merchants to evaluate sales differently. After a sale, SEB bookkeepers can separately record how physical resources changed, i.e., cash increased and inventory decreased. With DEB, one accountant must track both items, and will more likely consider future contingencies before recording a journal entry – e.g., can and will the customer return the product? Thus, DEB encourages the accountant

to consider different future scenarios to assess risks and uncertainties (Suddendorf and Corballis 2007; Seligman, Railton, Baumeister, and Sripada 2017), which encourages a prospective focus that can improve discovery of future profit opportunities.

Merchants seeking "just" exchanges likely considered broad moral precepts that go beyond recognition and valuation – e.g., does an accounting method "fairly" represent a transaction to third parties who use accounting data (Dickhaut et al. 2010, 246)? Norms of "best accounting practices" can lower the cost of profit identification for complex transactions, but where do these norms or principles come from? Littleton (1953) suggests that accounting principles emerged from practice commonalities and were identified through inductive reasoning. Gilman (1939, 169) describes these principles as "the common law of accounting," and Byrne (1937, 368-371) characterizes accounting principles as "discovered fundamental truths" that are "coercive and self-executory" and "must be obeyed if in the long run the enterprise is to survive."

Accounting principles were induced from practice through legal cases and accounting theory textbooks (Chatfield 1974; Baskin and Miranti 1997; Previts and Merino 1998). Auditing firms that observed and evaluated different practices across their clienteles, professional organizations that let accountants widely share knowledge, and standard-setting organizations like FASB played important roles in spreading these principles (Zeff 1972; 1986). Except for recent standard-setting, accounting principles have generally been the product of bottom-up trial-and-error evolutionary processes rather than top-down design decisions (Waymire and Basu 2007, 94-104; Basu 2015).[14]

Early textbooks and curricula in *abaco* schools emerged to store and diffuse the growing conceptual accounting knowledge.[15] Thus, a bookkeeper who learned DEB in 1500 CE using Pacioli's

[14] Smith (2003) labels evolved versus designed institutions as resulting from ecological and constructive rationality, respectively.

[15] Unlike most other species, humans have developed a large capacity for social learning using culturally stored and transmitted knowledge in addition to individual learning (Boyd, Richerson, and Henrich 2011).

Summa (1494) would know far less than an accountant who learned DEB in 1920 from Hatfield's *Modern Accounting* (1909). The accumulation of accounting knowledge lets future generations deal with even more complex transactions; thus, accounting practice can co-evolve with economic exchange in "ratchets" up to higher knowledge scaffolds (Tomasello 1999, 37). Institutions like DEB can change and expand in function as transactions and economic environments grow more complex, as the earlier discussion of the emergence of cost accounting in large manufacturers suggests.[16]

Beyond what is observable, the mental analysis of transactions *co-evolves* with accounting practice and economic exchange. Accountants observe large numbers of transactions and define categories based on "repetitive patterns that occur so frequently that people can recognize them by a short-hand explanation called an 'account'" (Ijiri 1993, 281). Repeated DEB transaction analysis reinforces a profit-focused mindset whereby, according to Sombart, "profit becomes an end which dominates the whole system" (Parsons 1928, 649).

This suggests that managers perceive future profit opportunities differently under DEB and SEB. People use mental models to make sense of their environment; such models are symbolic representations that imperfectly capture some crucial aspects of real-life events and interactions (Johnson-Laird 1983). For example, a mental model of the solar system could depict several marbles revolving around a basketball. Craik (1943, 61) notes that a mental model helps a decision-maker "try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and in every way to react in a much fuller, safer, and more competent manner." The crucial change of mental models in DEB over SEB comes from evaluating all transactions (even barter) using a single monetary unit rather than

[16] For example, the Industrial Revolution would have created a demand for more finely partitioned data on manufacturing costs, so that they could be controlled. Thus, measurement practices for inventories would likely differ from accounts receivable in being less sensitive to accounting regulation – e.g., Madsen (2011, 1695-1702).

different physical units. This common yardstick makes it easier to compare transaction profits across product types, trading partners, dispersed markets, or over time.

Hayek (1952, 123-4) suggests that mental models are represented in the connections between neurons and their patterns of interaction, and that these connections are crucial to memory formation and learning. Hebb (1949) and Hayek (1952) independently hypothesized that a person's experience shapes brain structures – i.e., the human brain is "plastic."[17] Barton, Berns, and Brooks (2014) report that earnings data are processed by the brain's reward centers. An accounting concept like revenue likely involves several neuronal groups, and links between neuronal groups representing related concepts (e.g., receipt and expenditure) are likely stronger. Accounting within the brain involves several regions (Farrell, Goh, and White 2014; Eskenazi, Hartmann, and Rietdijk 2016). Similarly, DEB-based transaction analysis will likely rely on memory functions distributed across brain regions involved in forecasting future profits (Seligman, Railton, Baumeister, and Sripada 2016; McClelland, McNaughton, and O'Reilly 1995; Hill et al. 2017).

We conjecture that the mental models constructed under DEB are more tightly linked to causal exchange interactions than those formed under SEB. DEB leads more directly to consideration of costs in connection with revenue generation since the DEBITS=CREDITS rule encourages simultaneously recording benefits *and* costs associated with transactions (Ijiri 1981, 21). Historical cost emerges naturally with DEB where resource value changes are recognized more quickly than with SEB, and this advantage is increased when a firm transacts more often and can more accurately predict future outcomes (Ijiri 1981, 26-32).

[17] Brain changes have been measured for musicians learning a new instrument and London cab drivers memorizing its map (Maguire et al. 2000; Munte et al. 2002; Nutley et al. 2014; Schlaug 2001). We expect that DEB has similar effects on accountants, e.g., enlarged brain regions with stronger connections in processing rewards, sacrifices, quantification, and social cognition.

We expect that the mental models constructed by DEB users will be better integrated with an understanding of the causal forces that underlie profit and reflect a better understanding of how current expenditure leads to future revenue and profit (Dichev 2008). For example, a DEB-based mental model would let a durable goods producer forecast more accurately how sales and costs would change if it offered a new product warranty. A DEB-based mental model focused on future profit will also better comprehend the "value chain" that makes a product desirable. This will help an entrepreneur decide whether to change a product element or to expand into markets for complementary products. DEB-based data from past transactions can help an entrepreneur conduct a "what if" analysis for future transactions based on their similarity to prior experience (Ijiri 1981, 29). We discuss why this ability improves the survival prospects of firms possessing this capability in the next section.

Researchers can also investigate how DEB use changes transaction analysis. Process-tracing techniques can be used to decompose the steps used by accountants in transaction analysis and how that process changes for firms adopting DEB (Ford et al. 1989). One starting point might be to explore how college freshmen analyze a profit-seeking transaction before they had been exposed to DEB in an introductory course.

Using a sample of students learning DEB for the first time, how do new accounting students learn to do basic transaction analysis before recording a journal entry for sales revenue? Does this vary as future cash collection becomes more uncertain for a given transaction? Do they start from previous cases, or do they begin with more basic notions of uncertainty and risk? Is this process affected by the history of interactions between the customer and a firm?

How does knowledge of basic accounting concepts affect transaction analysis? For instance, does an accountant analyze a complex sales transaction differently after being prompted to recall accounting principles on revenue and expense recognition? Does transaction analysis differ for individuals exposed only to recent FASB guidance on revenues versus those also exposed to older

perspectives on revenue realization (Paton and Littleton 1940; SFAC 5, FASB 1984, paras. 83-84)? A brain mapping experiment (e.g., fMRI technology) could help identify fundamental differences in DEB- vs. SEB-based transaction analysis.

A broader research question is how DEB shapes a businessman's mental perspective of profit generated by a firm's interactions with consumers. We predict that experience with DEB will help an entrepreneur better identify conditions where a small positive profit is more likely than a small loss and more accurately forecast overall profits and its components. Does higher quality DEB data on profits lead to better strategic decisions in response to environmental changes? A two-part laboratory experiment could be used to investigate these questions. A first task could have both accountants and non-accountants analyze a series of transactions and forecast future profits. A second task would have subjects interact through trading assets in a laboratory market with uncertain payoffs where subjects received either DEB or SEB data. We expect that subjects' payoffs will reflect their ability demonstrated in both the first stage transaction analysis and the quality of data they received later in the experiment.[18]

Researchers can also study how accountants internalize DEB by tracking physiological changes in student brains during their first accounting course. We envision an approach like Nutley, Darki and Klingberg (2014), who track whether children learning a musical instrument show increased working memory, reasoning effectiveness, and gray matter volume in brain regions known to be used in reading music. We could then see which brain regions are affected by learning DEB.[19] Are these regions the ones typically used in quantification, reward processing and social cognition? Do students with high grades in

[18] As an extension, it would be interesting to run an experiment in a barter economy versus a money economy. How much better does a money economy perform? Does SEB add less value compared to DEB in the latter setting?
[19] Dickhaut, Basu, McCabe, and Waymire (2010) and Birnberg and Ganguly (2012) discuss the prospects for neuroscientific accounting research more generally.

accounting courses exhibit more pronounced brain changes and/or did they have larger brain regions used in accounting tasks even before they start the course?

V. ADAPTIVE SIGNIFICANCE

Wilson (2019, 18) notes that natural selection occurs by testing new alternatives' *survival properties* in a specific environment. He summarizes how a biological trait evolves as, "mutation proposes, the environment disposes." Cultural innovations face the same selection forces as biological traits (Campbell 1960; Dawkins 1976; Richerson and Boyd 2005). In both types of evolution, the forces guiding selection can change over time if exaptation alters the main functional emphasis of a trait or institution (Gould and Vrba 1982; Johnson 2010, 151-75).[20] We suggest that DEB ultimately enabled more timely and accurate future profit discovery because of exaptation. That is, the main function of DEB shifted towards a greater emphasis on competitive profit discovery as firms grew in size and complexity during the Industrial Revolution.

DEB does two things to improve competitive profit discovery relative to SEB. First, DEB lets a merchant see what happened in the past more clearly than does SEB. A merchant can better distinguish products with small profits from those with small losses because they are measured in the same monetary unit and can winnow out unprofitable products to improve total profits. Second, DEB's timely and accurate profit data lets a merchant experiment with product changes and marketing activities and more accurately determine if these trials succeed using a single monetary unit. That is, DEB lets a merchant forecast future profits more accurately. We discuss these issues and present some historical examples in this section.

[20] According to Merriam-Webster, an exaptation is a "trait, feature, or structure of an organism or taxonomic group that takes on a function… that differs from its original function which had been derived by evolution."

Ijiri (1967, 102-105) uses "causal double-entry" to label how DEB helps a merchant understand profit sources better than SEB.[21] Ijiri (1993, 273) elaborates:

> "What is the role of flow accounts in relation to stock accounts? We note that flow accounts, such as income statement accounts, are there to explain or "account for" the reasons why stock accounts changed, either individually or in the aggregate. In the case of double-entry bookkeeping, what was added was this *explanation* by means of income statement accounts on why net assets (assets less liabilities) of the entity changed…
>
> In the single-entry era, this "explanans" is what was missing. As mentioned earlier, merchants could figure out net income by comparing the two balance sheets, but they could not know why so much or so little income was earned because the books of accounts had only information that described "what" happened and not "why." (*emphasis* in original)

We analogize DEB to a set of eyeglasses that sharpen eyesight relative to SEB – see Figure 1.[22] Absent eyeglasses, a merchant accurately sees total profit when his assets and debts are periodically valued under SEB (Panel A). However, his memory of profit from individual past transactions becomes fuzzy as increasing numbers and types of transactions tax individual memory. Panel B shows how eyeglasses sharpen the merchant's focus by letting him recall specific transactions more accurately using DEB, which makes higher value-generating transactions more salient. Thus, the mental model described earlier uses the sharper vision that results from using DEB shown in Panel B of Figure 1. That is, because DEB matches direct past expenditures to current sales, it elicits prospective analysis of future profit consequences before current expenditures.

The sharper vision of past results with DEB can help an alert entrepreneur better discover future profits (Kirzner 1973, 223; Hayek 1968, 181-2). Merchants react to price and order changes because

[21] The ledger accounts under DEB classify various effects of transactions – i.e., they are "categories" that "compress a mass of similar data into a single, significant total" (Littleton and Zimmerman 1962, 21). As a result, DEB generates useful data that merchants can easily access to support strategic and operational decisions. While profit data *could* be recovered from a SEB system, timely and accurate data on transaction-specific gross profit and periodic income sources are more readily generated and are far easier to find with an evolved DEB system.

[22] Jan Christoffels Ympyn (1547, Chapter 2) uses a similar metaphor in his DEB textbook when advising the merchant, "At least once in the year, to peruse and cast over his book to see what state and condition that he stands in, and not to proceed confusedly, not knowing whether he increase or go backward, whereby many persons have deceived themselves, but by this order and treatise (which may be called the merchant's glass) that inconvenience may soon be remedied and holpen" (quoted by Winjum 1971, 339-340).

they signal changed profit opportunities. In Hayek's words, entrepreneurs "direct their attention" to easily available data when evaluating environmental changes. These evaluations will likely be more accurate, and the responses more effective when the merchant is guided by the more precise and timely DEB data (Waymire 2009). Managers using DEB will better exploit available knowledge and leave fewer "free lunches all over waiting to be discovered or created" (Schelling 1995, 22) than would be the case with SEB.

Vatter (1950, 14) describes how accounting improves understanding of the past and leads to better predictions about the future:

> "The *dollar figures of accounting* are useful to management because they express what has happened in an understandable way; but accounting data may also serve, in part at least, to evaluate the desirability of past actions… Hence, records are kept to evaluate results so that desirable policies may be continued and undesirable ones dropped… By careful analysis of past results, it is frequently possible to forecast in a limited way what may be expected in the future…. (T)he reason for keeping records is not only to see where we have been, but also to shed some light on where we are going!"[23] (*emphasis* added)

Ijiri (1981, 33) extends this reasoning when he writes that historical cost data derived from DEB transaction records "provides a basis for developing criteria for choosing the best model among many since we prefer to rely on a model that worked well in the past, and whether a model has worked well or not must be determined on the basis of past records."

In effect, DEB's tighter causal connections can better simulate "mental time travel" that links the firm's current transactions to both past consummated exchanges as well as to future contemplated transactions. This mental time travel is useful because it integrates control (an activity focused on the recent past) and planning (a more future-oriented activity) (Ijiri 1981, 29). Planning by firms is improved by DEB use (Most 1973) since DEB applied to large numbers of "localized" transactions results in a

[23] Littleton (1953, 54-5) likewise suggests that the flexibility of DEB account categories lets accountants track and simulate different product costs to provide a vital input for future product decisions.

"complex whole" created by the "systematic accumulation of the localized (and "mechanistic" as Sombart called it) judgment on atomic exchanges" (Ijiri 1981, 27).

Many activities in managerial accounting involve mental time travel (Vatter 1950; Horngren 1962). In managerial accounting, past data in the accounts are used to develop current budgets and standard costs, which serve as the input to future analyses of cost variances. These data and analyses let the scale and scope of firm's operations be adjusted in light of new information.[24]

A single merchant using DEB (unlike his competitors) within a competitive discovery process (Hayek 1968, 181) can sell products at lower margins than his competitors. Competitors using SEB will likely lose by a small amount on average if they try to compete head on, but they can survive if they locate market niches. Similarly, a firm insulated from market competition by government-granted monopoly – e.g., the Dutch East India Company cited by Yamey (1964, 126-130) – would more likely survive using SEB. Like any management tool, more effective use of DEB will generate higher volume and profit and lead to positive skewness in the distribution of profits and firm size (Ijiri and Simon 1967; Demsetz 1973). Industries that invested early in modern information systems have more positively skewed profitability and firm size, consistent with our hypothesized advantage in assessing product-specific profit contributions (Bessen 2020). Identifying a competitive advantage requires that the entrepreneur accurately forecast future profitability. We believe that the mental time travel enabled in part by DEB aids such identification.

Several examples illustrate how an entrepreneur adjusts the scale and scope of his firm in pursuing higher profits. For example, a large-scale meat producer who supplies local butchers would

[24] Ijiri (1981, 26) argues that the benefits from using DEB likely are a function of firm scale and scope: "Like a small aircraft reflecting changes in temperature, not immediately but gradually, as heat exchange takes place, the records under historical cost gradually reflect changes in the environment in which the entity operates. The more frequently the entity transacts in the environment, the faster the change in the environment is reflected in its records. In this sense, the historical cost principle and double-entry bookkeeping made mass production of financial records feasible, just as division of labor and automation have contributed to mass production of goods."

need to know what products to sell and what prices to charge to individual butchers who eventually deal with consumers. How does this occur? U.S. meatpackers made extensive use of cost estimates in the 19th and early 20th centuries. Bliss (1922, 290) notes that these costing systems were based on "up-to-the-minute and reliable information as to costs" as well as "the most recent information as to the markets and costs of live animals." The costing systems of meatpackers (as in other industries) were built on a foundation derived from DEB's usefulness in storing classified cost data useful for marketing, production, and investment decisions (Garcke and Fells 1889, 4-11; Hawkins 1905, 1-10; Gilman 1911, 249).

In 1800, the U.S. meatpacking industry was comprised mainly of retail butchers who bought local farm animals and sold dressed meat in local shops. Meatpacking, like many industries, was transformed in the 19th century when wholesalers expanded nationally aided by the extensive U.S. railroad network and the invention of refrigerated boxcars (Chandler 1977, 299-301; Grand 1903; Hill 1923). Large beef wholesalers like Swift and Armour developed sophisticated product "cost finding" systems (Kimball 1917; Chandler 1977). Unlike manufacturers who combine inputs to produce a product, the cost accounting for a meatpacker is complex because a joint input (livestock) is divided into dressed beef and by-products like hides and fat (Putnam 1921; Bliss 1922).[25]

A 19th century meatpacker could earn much greater profits using DEB only if small profits from each transaction were scaled up to thousands of transactions. This seemingly small per-transaction effect, however, could be huge if we consider the cumulative effect across all firms worldwide. The result is that DEB may have a large aggregate effect and still not be well understood by decision makers or the scholars who study such behavior. More to the point, we have trouble grasping the significance of

[25] High common costs made it difficult to assign unique costs to the primary product and by-products (Greer 1936). The inventory cost of dressed beef was estimated as the purchase price of the livestock plus transportation, storage, and processing costs less the estimated market values of any intermediate by-products (Greer 1936).

DEB because we cannot observe the counterfactual performance of a firm or a macroeconomy where only SEB is available – i.e., nobody knows DEB's opportunity cost.[26]

Another example is Francesco Datini, a 14th century Tuscan merchant who accumulated hundreds of DEB account books and ledgers between 1350 and 1410 (Origo 1957/1986, 107-115). Datini used his accounts directly in his own activities and indirectly through several bookkeepers he employed to monitor foreign branches. His veneration of profit is evident in the invocation "In the name of God and of profit" on the first page of each new ledger (Origo 1957/1986, 109). Origo (1957/1986, 95) notes that, "Datini made his fortune, not so much by a series of brilliant *coups*, as by an infinitely patient accumulation of small profits – an avoidance of dangers, quite as much as a seizure of opportunities" (original *emphasis*). Other historical examples suggesting that DEB aids firms in wealth creation include Venetian shippers who used venture accounts to track profits in 14th century foreign trading ventures and British merchants who used venture accounting before 1700 (Pacioli 1494/1915, Ch. 20; Winjum 1970; 1972).

Nineteenth century steel magnate Andrew Carnegie is another exemplar in using DEB. Carnegie took a night school course as a young man to learn DEB and the partnership agreement at Carnegie Steel required that DEB be used for accounting (Bridge 1903, 5-8). Carnegie used a DEB-based cost accounting system to successfully implement a "cost leadership" strategy that let him undercut his competition on large jobs (Johnson and Kaplan 1987, 32-34). Carnegie's success was partly due to his having more accurate cost data than his SEB competitors who computed profits only once per year (Carnegie 1920, 135).

The kinds of weaknesses in cost accounting addressed by Carnegie were not unique to steelmaking. In discussing durable goods industries more generally, Garner (1954/1976, 29) remarks:

[26] The decisions reached when transactions are recorded under SEB would, over the long run, differ from those under DEB. Socialist systems that emphasized quantities and ignored prices in operational decisions are analogous to SEB, although the profit motive was consciously suppressed in these systems.

> "(I)t was the custom to estimate costs and tender bids to prospective buyers. What was more logical than to take the next step; that is, after accepting a contract for a certain project, to keep some sort of collective details as to the costs of executing the contract in order to ascertain the profit or loss thereon, and to provide information for future estimates? Obviously, this is known today as job order costing, and some of the modern cost accountants' most difficult problems grew out of those humble beginnings."

Other entrepreneurs who learned DEB early in life include German banker Jacob Fugger (1459-1525) and American industrialist John Rockefeller (1839-1937) (Steinmetz 2015, 10; Parr 2016). Sam Walton used profit data in managing the Ben Franklin "five and dime" store where he began his career. These data included "merchandise statements," "profit and loss sheets," and "little ledger books called Beat Yesterday books, in which you could compare this year's sales with last year's on a day-by-day basis" (Walton 1992, 30). He remarks "I had no previous experience in accounting – and I wasn't all that great at accounting in college – so I just did it according to their book. In fact, I used their accounting system long after I'd started breaking their rules on everything else. I even used it for the first five or six Wal-Marts" (Walton 1992, 30-1).

Since SEB firms could survive in turbulent environments (Yamey 2000) and transactional complexity was low for a long time, DEB diffused slowly. This likely explains, at least in part, why the effect of DEB on entrepreneurial behavior and mental attitudes spread very gradually. Nonetheless, we hypothesize that over the long-run (1) firms that adopted DEB earlier earned higher average profits, and (2) the spread of DEB beyond Renaissance Italy led to increased wealth in regions where entrepreneurs more frequently used DEB. This is, as already noted, consistent with a long-run co-evolution of DEB with mental models of exchange and increasing complexity and scale of profitable economic exchange.[27]

[27] DEB could also have indirect effects on economic growth. Sombart (1924, 118-119) argued that DEB led to future scientific laws. Basu (2015) suggests that this could have happened if DEB training created a mental model based on exchange value conservation that discoverers of scientific laws transferred to other domains. He points to several amateur scientists who used DEB professionally and discovered conservation laws for angular momentum (Isaac Newton), atomic mass (Antoine Lavoisier) and electrical charge (Benjamin Franklin).

Future research on DEB's adaptive significance should address two questions: (1) in an economy with easy access to knowledge about using DEB, which firms and industries first adopt DEB, and (2) does the introduction of DEB into an economy spur economic growth, and if so, with how much of a lag?

The starting point for these tests is a better understanding of how DEB spread to other countries beyond Italy, and when this occurred. Consider a measure equal to the percentage of large firms using DEB for every year from DEB's first appearance in 1211 CE to today. Figure 2 shows a *conjectured* plot of values for this variable, which we label %DEB. The plot of %DEB in Figure 2 reflects evolutionary change in the propensity of individual firms to use DEB. %DEB is a function of firms' knowledge of DEB obtained through either experience, interaction with other organizations (e.g., in a local business consortium), or through written texts such as Pacioli (1494).

Figure 2 shows that %DEB was likely indistinguishable from zero for many years after 1211CE since most firms beyond major Italian cities would be unaware that an alternative to SEB even existed. The figure conjectures further that %DEB increased after publication of Pacioli's *Summa* in 1494 since this and other books (1) aided the diffusion of know-how about DEB, (2) allowed potential adopters to better understand DEB's operational value, and (3) provided for more permanent knowledge storage that would extend beyond the life of a firm or its accountant (Littleton 1953, 3). We conjecture that %DEB would again increase after the start of the Industrial Revolution (ca 1800 CE) as very large manufacturers proliferated and discovered that profitable use could be made of DEB-based accounting information (Chandler 1977; Garcke and Fells 1889, 4-11). Finally, the figure depicts the likely universal use of DEB among large organizations today.

First steps towards understanding DEB diffusion would include a comparison between the earliest DEB adopters and other firms operating in the same places. What products were supplied by these firms? What scale did they achieve? Relevant data for such a study might exist in the Human Relations Area Files (HRAF), which provides coded data on ethnographic texts about the characteristics

of different human cultures. An accounting measure is provided in HRAF and this measure codes mention of double-entry bookkeeping.

Another opportunity is to study whether the geographical diffusion of DEB beyond Italy was historically associated with improved macro-economic performance. For example, one could track when Pacioli's original text was translated into different local languages or when the arrival of DEB was documented by ethnographers studying a country or region. One can then test for macroeconomic performance improvements following DEB introduction dates, although we must remember that DEB diffused unevenly within an economy – e.g., early uses of DEB (recording transactions) were more rudimentary than later ones (financial statement preparation).

Historically, firms that transacted in money would be more likely to adopt DEB because comparable prices across transactions are a prerequisite. Retailers who routinely bought and sold many products for cash and bankers who transacted in currency should have been more likely to adopt early. Our theory also suggests that the incremental gains from using DEB are greater for firms that have many exchange opportunities that yield modest expected profits. That is, DEB adopters are those with potential scale and scope economies, but which are less able to distinguish between small per unit profits and losses using only SEB. We argue that DEB firms would more likely become "cost leaders" with small profit margins than "brand differentiators" with large profit margins (Porter 1980). For example, Amazon and Walmart pursue a cost leadership strategy and offer many products that earn low per-unit margins. Industries that adopted DEB early should have more skewed profitability and firm size.

Obtaining data to test these predictions is difficult but not impossible. Comparative historical case research on early DEB adopters can be conducted using 13th and 14th century accounting archives. Detailed historical case research (e.g., Winjum 1970; 1972) on countries or regions with large archives could trace the effects of using DEB. Field experiments manipulating DEB availability for entrepreneurs

seeking micro-financing could measure profitability differences *ex post*. Laboratory experiments could be run where subjects can purchase DEB data to earn profit in economic games.

Another part of this research question is whether and how soon DEB introduction leads to greater realized gains in a firm and its economy. We suggest two ways to explore this critical issue. One is to examine changes in competitive dynamics within an industry when one or more firms gains access to DEB-based data. Are DEB firms within an economy better equipped to discover profit opportunities and produce gains from exchange than SEB firms? We imagine an agent-based economy simulation where each agent can gain from discovering profitable exchanges with "robot" buyers. Do agents with perpetual DEB-based contribution data earn greater gains from exchange than agents who have access to only periodic SEB-based profit data? The starting point would be an economy where only one agent has access to DEB and other agents only have SEB-based data. One could then explore how wealth generation changes when more agents use DEB. This could be extended by tweaking the size of possible gains from exchange, the complexity of exchanges, and the personal cost to implementing DEB. Collectively, data from this simulation would provide evidence on DEB's survival value over SEB.

VI. CLOSING REMARKS

We have hypothesized the evolutionary basis for DEB using Tinbergen 's (1963) four questions – proximate causality, ultimate causality, mechanism, and adaptive significance. In terms of proximate causality, no consistent pattern is evident in the historical record. Its first known appearance in Italy suggested it improved recordkeeping (Sangster 2016; Lee 1973, 1977) and Pacioli (1494) suggested it promoted prudent management. As DEB become more common, firms more often copied the habits of successful organizations. In contrast, we suggest that DEB's ultimate causation lies in how DEB and SEB likely led to differing behaviors by managers pursuing greater profits. This result is due to more timely

product-level profit identification under DEB even when no manager understands whether, how, and why their behavior is affected by DEB use.

We hypothesize that the mechanism leading to greater benefits to using DEB is the constraint in DEB that the sum of debits equals the sum of credits for each transaction. The DEBITS=CREDITS constraint leads an accountant to think differently because transactions generating a residual profit or loss encourage asking deeper questions about why a transaction is profitable when engaging in transaction analysis. We hypothesize that this deeper way of thinking about profit would have encouraged mental time travel where current profits were cognitively linked with past events (e.g., investment) and future contingencies. The change in thinking that likely accompanied DEB use is DEB's adaptive significance. Specifically, the stronger relationship between past, present, and future improves profit discovery under DEB relative to SEB. In other words, DEB can improve identification of past profits for specific types of transactions, which is in turn leads to better knowledge of the kinds of transactions that are likely to be profitable in the future.

Our analysis is conjectural in two important ways. First, our evolutionary theory may be a precursor to genuine knowledge about the value of DEB, but without evidence we cannot know whether our hypotheses about DEB evolution is valid. We have offered several suggestions for empirical testing, and hope that future work will study them. Second, we have long known that DEB is an evolved accounting practice, but a corollary to that is that DEB will continue to evolve in the future. Future corporate accounting systems might resemble the triple-entry system of Ijiri (1989) or improved information technology might enable the production of financial statements using a basic system rooted in SEB.

Like Ijiri (2005), our perspective on DEB is dualistic. First, DEB measures profit contribution from *past* transactions, but its main consequence is better discovery of *future* profit opportunities. Second, the collective benefits of DEB could be huge but go unnoticed because the benefits accrue in small

increments over many transactions. That is, DEB could have a big unrecognized economic impact akin to a "vein of water flowing hidden underground, secretly making the ground green" (Carlyle 1888, volume VI, 107). Parsing out the unique effect of DEB on the wealth of firms and societies will be difficult – i.e., "endogeneity" will be omnipresent in naturally occurring data. Designing laboratory experiments that address endogeneity will be difficult, and may only demonstrate how the data that *could* be produced under SEB yields different economic outcomes than the type of data that was likely provided by DEB.

The big question underlying our paper, which may ultimately be unanswerable, is: how did DEB alter the world? More precisely, if accounting knowledge had been frozen at levels present before DEB was invented (c. 1,200 CE), would our world be the same as the one we live in today? Basil Yamey proposes that not much would be different had accountants used SEB for the past 800 years. A.C. Littleton, Yuji Ijiri, and we take the view that DEB had a profound effect on human existence. Determining how well these views capture DEB's influence is an important endeavor for future accounting research.

Distinguishing these perspectives will require scientific exploration at the core of modern accounting. We cannot otherwise avoid the ubiquitous "unintended consequences" of policy changes to institutions about which we know much less than we think we know (Merton 1936; Hayek 1945). Empirical evidence suggests that accounting data properties have changed fundamentally in recent decades (Basu 1997; Dichev and Tang 2008; Bushman, Lerman, and Zhang 2016), supporting the need for additional research on the foundations of accounting. A better understanding of why these foundations likely lie in the efficient management of firms rather than in reporting to external parties will be a worthy endeavor (Waymire 2009).

Over the long-run, this research will let us coherently answer future students who ask why we only teach them DEB-based accounting and devote no time to SEB. Hatfield (1924, 253) suggested a partial answer about DEB:

> "(I)n its origin it is respectable, nay even academic; that despite its present disrepute it has from time to time attracted the attention of men of unquestioned intellectual attainment; that it justifies itself in that it has arisen to meet a social need. Its functions are to locate responsibility, to prevent fraud, to guide industry, to determine equities, to solve the all-essential conundrum of business: "What are my profits?"; to facilitate the government in its fiscal operations, to guide the business manager in the attempt to secure efficiency. Are not these efforts worthy of any man's attention?"

A coherent theory of why DEB evolved as it did may also help us attain greater respect as an academic discipline (cf. Demski 2007). At worst, future entrepreneurs would better understand why DEB is important for the success of their businesses, and that would be a good outcome too.

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Table 1
Double-Entry Bookkeeping: Four Evolutionary Questions

1. *Proximate Causation*

What does DEB do in the short-run?
DEB's flexibility historically has served multiple functions that include more accurate recordkeeping, improved business ethics, and more accurate profit measurement.

2. *Ultimate Causation*

How has DEB evolved through time?
DEB firms survive in the presence of selection pressures that favor firms that are successfully generate wealth through for-profit business transactions involving products & services offered to consumers.

3. *Mechanism*

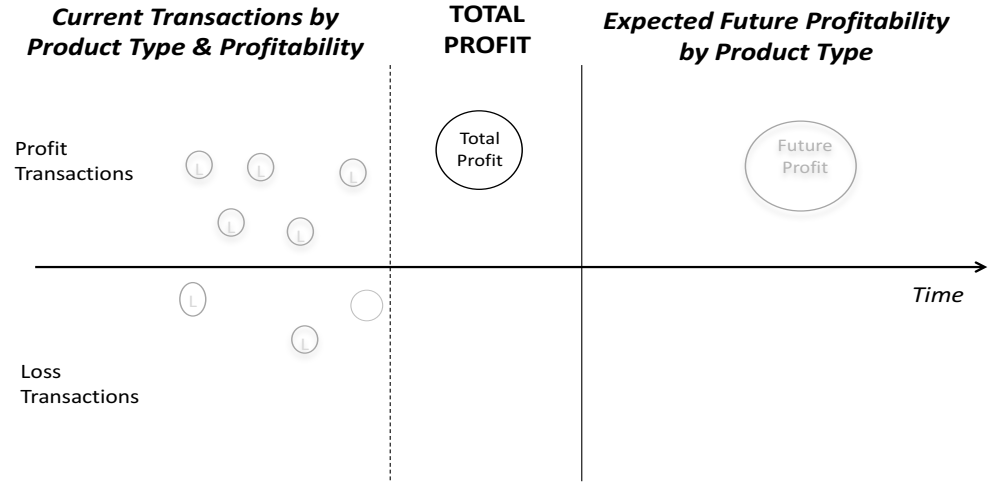
How does DEB change over time in complexity?
DEB through time has become increasingly complex through a system of accounts that are "fit" iteratively by applying the DEBITS=CREDITS constraint.

4. *Adaptive Value*

How does DEB affect firm survival?
DEB's better profit identification for past transactions provides a critical input for discovering future profit opportunities when a firm expands in scale & scope.

Figure 1
Clarity of Past & Future Profitability with SEB vs. DEB

A: SEB



B: DEB

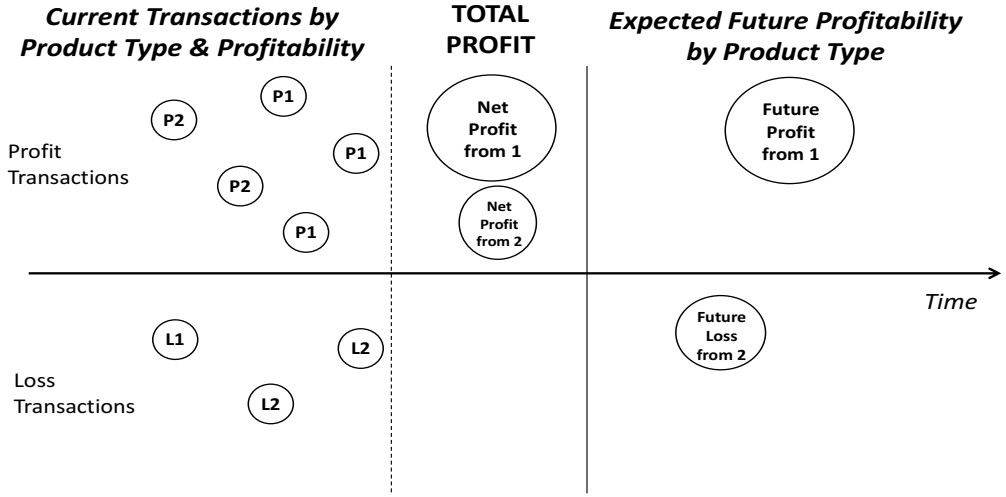


Figure 2
Conjectured Worldwide % of Firms Using DEB, 1211 CE – Present