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The Economic Value of DEBITS = CREDITS

ABSTRACT

Double-entry bookkeeping (DEB) dates back to the 13\textsuperscript{th} century, but its economic function is still not fully understood. Single-entry bookkeeping (SEB) records immediate resource changes for a transaction in physical units only with monetary profit measurement usually delayed until the books are closed. DEB requires that items exchanged be recorded in monetary units alongside physical units, with a residual wealth change reckoned to meet the DEBITS=CREDITS constraint. These seemingly mundane changes slowly move bookkeeping from a narrow focus on recording current events to also estimating wealth changes by evaluating future contingencies. We theorize that DEB gradually displaced SEB because it routinely produced more precise and timely data on transaction-specific contribution to profit, which ultimately quickened economic growth. Our theory yields testable predictions for the impact of DEB on (1) the process of transaction analysis, brain development due to learning accounting, and the evolution of accounting principles, and (2) the performance of organizations and economies in producing gains from economic exchange.

Keywords: double-entry bookkeeping, economic exchange, profit measurement, discovery process

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. RESEARCH QUESTION AND OVERVIEW

Research Question

Double-entry bookkeeping (DEB) was first used in 1211 CE by banks in Florence, Italy (Lee 1973; Sangster 2016). The method spread to the rest of Italy, Europe, and eventually around the globe. DEB has gradually displaced single-entry bookkeeping (SEB) and is used today by publicly traded corporations and for teaching accounting worldwide. Why does DEB dominate all other accounting systems? DEB has a built-in check on bookkeeping accuracy because debits must always equal credits in sum, but is this truly why large organizations use the difficult-to-learn DEB more than the simpler SEB? ¹

A century ago, several economic historians made bold claims for the importance of DEB. Werner Sombart (1902) asserted that DEB played a central role in the development of capitalism (Nussbaum 1933, 158-161). Max Weber argued similarly 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.” Joseph Schumpeter (1950, 123) wrote, “Capitalist practice turns the unit of money into a tool of rational cost-profit calculations, of which the towering monument is double-entry bookkeeping.” Mises (1949, 231) suggested that DEB “makes success and failure, profit and loss ascertainable,” and that “Goethe was right in calling bookkeeping by double entry ‘one of the finest inventions of the human mind’.”

¹ We focus on profit-seeking entities, but our analysis applies to any organization in which managers control the use of resources. Thus, our analysis would apply to a charity or government unit whose operational efficiency is evaluated with cost-benefit analysis using accounting data.
These claims are difficult to evaluate. First, they are hard to reconcile with the historical fact that firm-wide income statements were not produced routinely until the 19th century (Yamey 1949; 1964). Thus, a good theory must explain how DEB’s structure and effects on entrepreneurial behavior could evolve slowly. Second, accounting institutions do not embody individual or organizational goals; rather they likely aid in the achievement of multiple goals. Third, and most important, the Sombartian hypothesis does not specify how and why DEB could generate more wealth than SEB. Absent such detail, Sombart’s hypothesis remains an intriguing yet untestable conjecture.

We theorize concretely about how and why DEB improves entrepreneurial wealth generation over SEB. We hypothesize that the main advantage of DEB relative to SEB is the DEBITS=CREDITS constraint that requires recurrent valuations for purchases and profit contribution measurements for sales. Basic DEB helped entrepreneurs to acquire more timely and precise data on profit contribution that aided discovery of future profit opportunities and strengthened feedback from product and factor markets to business decisions. If valid, our hypothesis suggests that Yamey was right that DEB did not “cause” the emergence of capitalism, but Sombart and others were also likely correct that DEB increased economic growth indirectly by hastening the discovery of future profit opportunities.

Overview

Digital-native teenagers cannot imagine life without smartphones and the internet. Similarly, accountants find it extraordinarily difficult to conceive how the world would differ had DEB never been invented because they have always studied DEB. To grasp our intuition, imagine a modern organization using SEB, a 13th century tool, to account for complex exchange transactions. In this scenario: (a) each ordinary sale involves a cashier who tracks only cash changes and a warehouse clerk who separately

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2 We use “profit” and “contribution” synonymously to label the difference between revenue and direct (variable) costs associated with a sales transaction.
monitors inventory changes, (b) explicit profit calculations occur only when the books are closed and the change in net assets is appraised, (c) revenues and expenses are not tracked, and (d) product cost discovery for complex manufacturing firms is so cumbersome that significant vertical integration is rare.

We hypothesize that DEB enables quicker discovery of future profit opportunities by overcoming two limitations of SEB. First, SEB-based transaction analysis identifies only immediate resource changes (i.e., the changes in inventory and cash) and ignores the residual wealth change from a sales transaction. This is sensible if the main goal is to control resources rather than assess operating profit. Second, the requirement to equate debits and credits in DEB forces a faster reckoning of profit or loss that helps to discover changes in future profit opportunities more quickly than could be done with SEB data.

The pre-DEB world ran mainly on barter. If a farmer swaps one cow for five sheep, the farmer reduces his “cattle inventory” by 1 and adds 5 to his “sheep inventory.” SEB tracks resource inflows and outflows using physical units (e.g. heads of sheep, jars of oil, rolls of cloth). Thus, even in a cash sale, SEB tracks the inventory and cash changes in distinct physical units (e.g. sheep and coins). SEB obscured the measurement of wealth changes because it was difficult to net opposite changes in different units, i.e., the apples and oranges problem. Not surprisingly, wealth changes were rarely calculated using SEB.

Coins made from precious metals replaced shells, cattle and grains as money c. 2000 BCE (Davies and Davies 1996). Standardized coins spread in use, but barter transactions remained common. The emergence of a money economy was crucial because DEB assumes that every product can be valued and that voluntary exchanges are of equal values so that total debits always equal total credits (Schelling 1995; Basu 2015). DEB’s DEBITS=CREDITS constraint can be applied only with a single unit of account that lets every transaction be checked for equality and allows transactions to be aggregated. While debits and credits are easy to determine from quoted prices today, DEB was difficult to use in a mainly barter economy with many circulating currencies because DEB requires merchants to record all transactions in a local currency as debits will always equal credits only in a single currency (e.g. Paton
and Littleton 1940, 11-13). To record the earlier barter transaction, a DEB accountant must identify money prices for the cow and sheep while ensuring that their sums equalize.

If the cow is deducted at its recorded cost, then an equity (or net assets) account is needed to balance the journal entry. This equity account perpetually tracks the owner’s wealth and enables more precise and frequent wealth monitoring. The revaluation of retail inventory at the time of sale from the original cost measures the wealth change over the operating cycle, identifying and recording new contribution data. DEB works like eyeglasses that help an entrepreneur see clearly how much specific transactions, products or customers had increased or reduced his wealth ex post. These wealth effects were blurry when only resource unit changes but not their money values were tracked under SEB.

As transactions became more complex (e.g., multi-period transactions with future delivery and/or payment), new questions arose about ex ante valuations or cost. Consistently valuing purchases under the DEBITS=CREDITS constraint exposes a latent demand for conceptual knowledge about how to account for different transactions. Unlike SEB in which only resource unit changes are tracked, DEB’s DEBITS=CREDITS constraint requires consideration of future contingencies to identify how and why a transaction alters wealth. These contingencies include uncertainty of future customer payments for credit sales, customer rights of return, and future performance obligations of the firm (e.g., warranties). The result is that DEB transaction analysis fosters deeper thinking about economic exchange than SEB.

Of course, firms using SEB also sought profits and often generated positive profits. Thus, for a small firm, using DEB would likely yield modest efficiency gains. But as a firm expands to offer new products with different profitability prospects, timely and precise profit data become more valuable. With DEB, the records of changes in cash, inventory, and wealth for a transaction are cross-linked and DEB’s DEBITS=CREDITS constraint ensures that the firm obtains a sale-specific profit estimate.

We suggest that the DEBITS=CREDITS constraint has important micro-level implications for the subsequent co-evolution of mental exchange evaluation and entrepreneurial decisions that affect the
scale and scope of organizations. DEB fundamentally alters transaction analysis through study of future contingencies and their related wealth changes. Repeated DEB use changes individuals’ mental models of economic exchange, which leads to neuronal changes in their brains. Attempts to increase profits led in due course to separately recording, classifying and analyzing the expenses that generate revenues, especially services that create unrecorded intangible assets. DEB-based prospective transaction analysis thus activates a demand for systematic procedures for revenue and expense recognition.

DEB use by firms can lead to macro-level effects that enlarge firms and the wealth they create. Because DEB works like eyeglasses that help an entrepreneur to distinguish products that generate small positive profits from those that lose money, DEB can guide firms’ investments to better opportunities and cost-leadership strategies. DEB also helps track product market experiments to identify successful new products. The more accurate and timely DEB feeds back data from product and factor markets to operating decisions more quickly. DEB-based profit contribution measures can thus guide exchange to increase realized gains (Waymire 2009). Our micro- and macro-level predictions can be tested using experimental data from the laboratory and the field, naturally occurring data, and simulation models.

We build upon earlier work on the links between individual economic behavior, accounting institutions, and how people evaluate economic exchange. Basu and Waymire (2006) theorized that the core recordkeeping function of accounting alleviates memory limits; evidence from archaeology, economic experiments and ethnographic data is consistent with this hypothesis (Basu, Dickhaut, Hecht, Towry, and Waymire 2009; Basu, Kirk, and Waymire 2009). Accounting principles like Historical Cost and Conservatism parallel how the brain evaluates economic exchange (Dickhaut 2009; Dickhaut, Basu, McCabe, and Waymire 2010) and improves firms’ survival prospects (Basu & Waymire, 2011, 2018).

Earlier accounting scholars played an important guiding role for our evolutionary theory of DEB. Hatfield (1924) argued that bookkeeping by double entry served multiple functions and A.C. Littleton recognized the central role of DEB-based income measurement in providing useful data to managers of
organizations (Littleton 1933; Littleton 1953; Littleton and Zimmerman 1962). Yuji Ijiri (1967; 1975; 1993) wrote about the central importance of DEB as a device to powerfully orient thinking about the causes of profit generated from exchange. Kenneth Most (1972; 1973) advances a managerial planning hypothesis based on Sombart’s work. We seek to refine this thinking to parsimoniously explain a ubiquitous but poorly understood feature of accounting practice.

We offer two caveats. First, just as Steve Jobs did not foresee all the uses that buyers would put iPhones to, we hypothesize that the first DEB adopters could not perceive all the future benefits of DEB. We theorize that DEB only took hold after enabling conditions such as a money economy and algebraic reasoning were in place, and that a firm’s operations were complex enough to benefit from DEB. Thus, the gains actually realized from using DEB depended on the ability of entrepreneurs to conceive of and consummate complex transactions as well as the success of their experiments with DEB. Thus, DEB could spread slowly over centuries in a pre-scientific world where knowledge was generated by trial and error.

Second, DEB emerged as a management tool that would, in part, determine a firm’s scale and scope of operations by improving a firm’s ability to discover new profit opportunities. DEB operates through “multiplier” effects that increase gains from existing entrepreneurial profit discovery under SEB rather than as an independent cause of economic gains.

We first provide historical background from the oldest transaction records in 8,000 BCE through the evolution of modern DEB methods. The advantage of DEB over SEB is then described in greater depth. We next state our main hypothesis about the role of DEB in the co-evolution of accounting, the mental evaluation of economic exchange, and the economic performance of firms and economies. We then predict how DEB use leads to micro-level effects in transaction analysis and macro-level effects on the structure of and gains from economic exchange. We summarize proposed tests of our hypothesis before concluding.
II. HISTORICAL BACKGROUND

Understanding why DEB displaced SEB requires that we situate DEB historically. Table 1 summarizes characteristics of accounting, economic exchange and related institutions over four periods. The columns indicate periods when the most advanced form of accounting was recordkeeping (8,000 – 3,200 BCE), SEB (3,200 BCE – 1,200 CE), “basic” DEB without financial statements (1,200 CE – 1,550 CE) and modern DEB with income statements (1550 CE to present). We focus on the transition from SEB to DEB but discuss modern DEB financial statements often.

Panel A of Table 1 displays four accounting characteristics that changed over time. The first is the unit of account, which was in physical units until SEB and in a single currency once DEB was in place. The format of transaction records ranges from rocks, strings, clay tablets and papyrus in the recordkeeping period, to paper and electronic records in modern times. These media successively reduced the cost of high-fidelity data storage. Record content ranges from transaction details (5 W’s: who, what, where, when, why) to debits and credits with linked real and nominal accounts under modern DEB. The links between DEB records are important because they make past transaction data easy to find. A fourth accounting characteristic includes formal financial statements and their precursors, which includes asset and debt lists with SEB and trial balances under early DEB. In sum, panel A indicates that accounting systems co-evolve on multiple dimensions as time passes – bookkeeping changes from basic transaction records to complex records that store more and better-organized data and can be combined into trial balances and financial statements.

The lower panels describe changes in economic exchange (panel B), production (panel C), credit (panel D), law and organizational forms (panel E), and thinking modes (panel F). The move from barter exchange to a mix of barter and monetary exchange in the SEB era is consistent with accounting records

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3 The recordkeeping column is 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.
becoming more complex as exchange complexity increases. Accounting also co-evolves with production techniques, credit use, the complexity of law and organizations and thinking modes.

We make three larger points about Table 1. First, the changes listed in Table 1 were not “clean” and “linear” historically because some changes mattered more. For instance, economy-wide use of money in exchange is crucial because DEB uses price-aggregates and will not work without a single monetary unit for valuation. Further, accounting techniques died when empires fell and had to be rediscovered or reinvented by future civilizations, so long-term progress masks many large short-term reversals. Second, accounting changes are not isolated but rather co-evolve with concurrent changes in markets and economic organization. Third, being “concrete” does not make something important. Services have superseded manufactured goods in developed economies, and as we assert later, cognition and modes of thinking are central to understanding the effects of DEB.

We now describe each accounting era in more detail. The oldest-known transaction records are the baked clay tokens produced about 8,000 BCE in Mesopotamia (now Iraq) in the first farming villages (Schmandt-Besserat 1992a; 1992b). The earliest tokens were simple shapes (e.g., spheres, cones, and disks) that represent concrete physical quantities of cultivated grain and abstract mental units of labor. These initial records likely lengthened planning horizons since farming takes months compared to the daily food-gathering plans of nomadic hunter-gatherers. A sedentary lifestyle let farmers amass property and livestock that were soon marked with ownership emblems; property claims likely led to a shift from generalized reciprocity within the kin group to balanced reciprocity with individuals (Sahlins 1972).

Over time, more goods were symbolically represented by varying the size, shape, and markings of the tokens. The tokens show that Mesopotamians distinguished between different classes of goods, each with differing qualities and sizes. 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 eased private dealings between individuals, especially multi-period contracts where performance tracking mattered. These multi-period contracts sparked running records that we now call bookkeeping.

Writing first appeared in Egypt around 3,400 BCE and in Mesopotamia near 3,100 BCE, i.e., the transition from recordkeeping to SEB in Table 1. In both cases, writing progressed from pictographs to phonograms that were combined in hieroglyphic script (Champollion 1824; Mouck 2004). The Egyptians kept records on papyrus, a thin paper-like material, by the reign of the Pharaoh Khufu, c. 2560-2550 BCE (Tallet 2012). Similar to the Mesopotamian tokens, the oldest Egyptian records store data on village-level taxes and arrears (e.g. Farag 2009), which led to early SEB with classified accounts. Scribes kept detailed inventory lists for the royal storehouses that collected in-kind (usually grain) taxes.

Figure 1 shows the structure of SEB records kept by an Egyptian farm manager, Zeno, in the third century BCE, for the owner, Appolonius (Grier 1932). The seven-thousand-acre farm was organized as several functional departments. Each department’s accountants kept daily records of inflows and outflows of pigs, goats, hoes, axes, barley, bran allowances for animals, castor oil, linen garments, rugs, etc., similar to a modern perpetual inventory system for each department in physical units only. Numerals were recorded in a column at the far right, likely to ease computation of net balances that were transferred to monthly and annual accounts, similar to a petty cash system. Workers were paid in grains (a food allowance) that were tracked separately from money even in the annual accounts.

This extensive SEB system could closely monitor the activities of thousands of people, consistent with Yamey’s positive assessment, but it was very difficult to assess wealth changes let alone conceive of “maximizing” wealth by adding up different physical units (Mickwitz 1937). This non-monetary system recorded the directed transfers between different departments that produced most of the farm’s needs, for which market prices and valuations were largely irrelevant. As noted above, ancient Egyptian

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4 Tracking in physical units under SEB extended to money, especially when coins were intrinsically valuable for their precious metal content. Thus, instead of determining the total value of money held, the bookkeeper would physically count each type of coin issued by different kingdoms or even different rulers of the same kingdom.
government records had a similar structure, which facilitated control and accountability. Single-entry bookkeeping systems were invented and used by many civilizations including the ancient Sumerian, Greek, Cretan, Roman, Chinese, and medieval European, Incan, Mayan, Indian and other empires.

Even in thirteenth century Italy, SEB accounts were running totals that increased or decreased as resources came in or left a given location. The accounts were kept in physical units and were rarely denominated in money. Most importantly, changes in different inventories were recorded separately, often by different bookkeepers, to lessen collusion between department managers. In contrast, DEB requires a central bookkeeper to simultaneously record changes in multiple accounts (separation of duties). Each journal entry thus satisfies the DEBITS=CREDITS constraint, which provides bookkeeping discipline and facilitates an audit. The cross-links facilitate cross-checking and auditing and also make it more difficult to alter records later while still balancing the debits and credits across multiple accounts.

Littleton (1927) identified money, writing, arithmetic, private property, credit, commerce, and capital as institutions needed for DEB to function well. Although all of these institutions were available to Zeno and his accountants, their SEB system did not progress to DEB, possibly because most of their transactions were internal without market prices. Perhaps most importantly, there was no reason to suspect ex ante that debits should always equal credits before DEB was invented (Schelling 1995).

Two of Littleton’s (1927) institutions were especially important for the transition from SEB to DEB: money and arithmetic, or rather, algebra. Fibonacci (1202/2002, Chapter 9) shows how to calculate the quantity needed to ensure an equal or “just” barter:

“(W)hen you will wish to exchange some merchandise for another merchandise, that is barter, you recall the price of each merchandise, which prices must always be in the same currency, and you write down one of the merchandise at the head of a table, and you write the price of the merchandise in the table afterwards towards the left in the same line, as we taught with the negotiations in the preceding chapter. Next in another line below the price of the merchandise you write the price of the other merchandise, and afterwards you write the quantity of the other merchandise.... For example, 20 arms of cloth are worth 3 Pisan pounds and 42 rolls of cotton are similarly worth 5 Pisan pounds; it is sought how many rolls of cotton will be had for 50 arms of cloth.” (emphasis added).
Fibonacci gives an algorithm using proportions (skipped for brevity) to calculate that exactly 63 rolls of cotton can be had for 50 arms of cloth, or vice versa, but this calculation requires prices to be in the same currency.\(^5\) Merchants conducting “just” exchanges would want to record the value traded with supporting price and quantity data to be used as proof in any future disputes or legal proceedings. While the earliest DEB records write out debits and credits as a narrative, Fibonacci’s suggestion to write down the data on items exchanged on successive lines prefigures the later practice of recording debits and credits on separate lines.\(^6\) Recording DEBITS=CREDITS for every transaction captured a socioeconomic reality enforced by algebraic calculations, which Fibonacci imported into Italy from his Arab education.

While coins appeared three thousand years before DEB, the bill of exchange was an important monetary innovation near DEB’s emergence (Ferguson 2008, chapter 1). In general, any commodity that serves as money must be portable and easily exchangeable (Menger 1892). The bill of exchange is a financial instrument by which a banker in one city issues credit to a merchant that can be used later to buy merchandise in a different city using a different currency.\(^7\) Fibonacci’s algebraic method for ensuring equal barter transactions was very useful for converting bills of exchange issued in foreign currency.

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\(^5\) Although DEB is superficially a simple additive algebra of values (e.g. Ellerman, 2014), it actually incorporates a more complex multiplicative algebra of prices and quantities that are combined to calculate values. Heeffer (2011) and Dean, Clarke and Capalbo (2016) also link the algebra of proportions for barter transactions to DEB, although they attribute Fibonacci’s computations to much later sources that were closer in time to Pacioli’s *Summa*.

\(^6\) Fibonacci (1202) immediately preceded the oldest DEB records in 1211, but we cannot directly link this text with recording debits and credits on successive lines. However, “For three centuries or so a curriculum based upon Leonardo’s *Liber Abaci* was taught in Tuscany in schools of abaco normally attended by boys intending to be merchants or by others desiring to learn mathematics” (Sigler 2002, 5), so it almost surely influenced generations of DEB accountants. Pacioli’s printed *Summa* supplanted the hand-copied *Liber Abaci* as a standard text in abaco schools three centuries later by adding new materials including the section on DEB aimed at merchant apprentices.

\(^7\) The Medici Bank of Venice was a *banchi grossi* (“great bank”) that financed extensive foreign trade by issuing bills of exchange (de Roover 1946). The bill of exchange requires a bank to have branches in many distant cities, which raises stewardship issues between branch managers and the owner. Thus, basic DEB had to let owners monitor their agents, which could be done by comparing the profitability of different branches for similar transactions, after reconciling copies of each branch’s DEB accounts with those of other branches and the headquarters branch.
III. THE ADVANTAGE OF DOUBLE-ENTRY OVER SINGLE-ENTRY BOOKKEEPING

We now elaborate on the informational advantage of DEB, which is to give entrepreneurs more precise and timely profit data than SEB. Specifically, DEB’s value lies in routinely measuring contribution to profit for each sale, which helps entrepreneurs learn about (i.e., “discover”) opportunities for profitable future exchanges. To better explain the benefit of DEB, we first review how exchanges are recorded under SEB and DEB, and then describe how this can lead to different future exchanges.

We start in a barter economy where goods are traded but there is no money. A relative price is the number of units of a product that can be traded for one unit of another. With no numeraire, a pure barter economy has many relative prices, e.g., with 200 products we can have $19,900 = \frac{(200^2 - 200)/2}{200}$ unique relative prices. In a pure barter economy, a price-aggregate (i.e., price per unit times the number of units bought) cannot be defined that makes transactions comparable in economic value. Thus, SEB in a barter economy tracks only the physical quantities of each commodity. If a farmer trades one cow to get five sheep, these changes would be recorded as fewer cattle (-1) and more sheep (+5) owned.

Three features of barter are important for our purposes. First, identifying trading partners who have what you want and want what you have (“the double coincidence of wants”) is not easy, so bid-ask spreads can be large (i.e. a farmer might accept five sheep but someone who wants to buy a cow may have to offer six sheep). The general acceptance and greater divisibility of money reduces search and transaction costs (Brunner and Meltzer 1971). Second, in a cashless economy, all accounting is accrual accounting, at least from a balance sheet perspective. Third, a DEB accountant cannot balance a journal entry without a single unit of account. Thus, even in a single-currency economy, SEB will not ensure that decreases and increases in accounts equate because accounts are kept in different physical units.

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8 Dechow (1994, 35) assumes, “that realized cash flows are a more ‘primitive’ performance measure than earnings. The value added by accountants is in accruing cash receipts and disbursements so as to attain a more useful measure of firm performance over short measurement intervals.” In historical terms, this assumption is inaccurate in that accounting was done for millennia in barter economies before there was cash.
In the cow-for-sheep trade, assume that the farmer originally paid $500 to buy the cow, and the five sheep have an appraised value of $550. Even if the farmer uses SEB (anachronistically) in money units, local bookkeepers could reduce the value of cattle owned by $500 and increase the value of sheep owned by $550 since these are independent adjustments to two distinct and unrelated inventory accounts. The wealth increase of $50 from this round-trip exchange (we ignore any costs and benefits between purchase and sale) would be hidden if the farmer only measured his net assets periodically. A farmer using pure SEB could review his original purchase records (if well organized) and calculate the wealth change from a given sale. Under basic DEB, a single accountant would always reckon the wealth change from trading a cow for five sheep when the trade occurs, and record the following entry (with prices and quantities in the memorandum to the journal entry and in the ledger accounts):

<table>
<thead>
<tr>
<th>Account</th>
<th>Debit</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep on Hand (DR)</td>
<td>$550</td>
<td></td>
</tr>
<tr>
<td>Cattle on Hand (CR)</td>
<td>$500</td>
<td></td>
</tr>
<tr>
<td>Owner’s Equity (CR)</td>
<td></td>
<td>$  50</td>
</tr>
</tbody>
</table>

The definition of owner’s equity as a residual claim measuring the difference between assets and debts likely changed how entrepreneurs viewed their business activities. Russell and Whitehead (1910, 11-12) emphasize that definitions are crucial because (a) they point to something important worth understanding, and (b) they 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 and measured through the “balance-sheet equation,” entrepreneurs would naturally focus on increasing this wealth measure. Since most Italian businesses were family enterprises, the new definition of equity likely spurred a separation of commingled personal and business accounts. Pacioli (1494/1914, chapter 20) explains how separating business and personal accounts, and also separating accounts for different types of transactions, leads to more precise data on wealth changes:

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9 These arguments are part of Sombart’s Hypothesis (Yamey 1949, 99-100), although usually applied to later, more-developed DEB with income statements.
“(C)ertain well-known and peculiar entries should be made which are of the highest importance in commerce, and which usually are kept separate from the others so that they can show their respective profits and losses (pro e danno). They cover tradings, partnerships, suggested business trips, trips on your own ventures, commissions from others, drafts (ditta) or bills of exchange (bancha descritta), actual trades, store accounts, etc.... This is done because, 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.”

Similarly, Thompson (1777, book II, chapter I) argues that accounts for different products lead to more precise data on wealth changes, and subsequently, better management (emphasis added):

“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.”

Much earlier, Cotrugli (1458/2017, 59-61) highlighted perpetual contribution data when he 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) also stressed the importance of profit data by type of merchandise (Yamey 2000, 4-5).

Cross-referencing of entries creates linkages within and across transactions that help an entrepreneur more easily access past data to understand why one type of transaction may be more profitable than another type and adapt business decisions in response.10

The surviving records for Rinieri Fini & Brothers (1296-1305) and Giovanni Farolfi (1299-1300), Florentine firms operating in France, suggest that the main elements of DEB had emerged by the late 13th century (Lee 1973, 1977). The surviving “General Ledger” of the Giovanni Farolfi branch in Salon

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10 We argue that DEB makes it easier to discover product-specific profits, not that such discovery 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 contributions 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 basic DEB, contribution was only calculated periodically rather than perpetually. Periodic valuations of assets and debts under SEB are sufficient to implement the FASB’S fair-value-based balance-sheet approach without all the complicated computations of DEB, raising the question of why we teach DEB or test it on CPA exams.
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 Expense Book and a Cash Book (Lee, 1977). This inter-related set of books has separate perpetual inventory accounts for many types of merchandise 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. The surviving ledger reflects understanding of the accounting entity, algebraic opposition between debits and credits, single 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).

When wealth-seeking exchanges are frequent, material, heterogeneous and span long periods, DEB is valuable for measuring how much wealth has changed due to different past transactions. Besides tracking quantities like SEB, DEB requires a merchant to track prices to value exchanges, which lets him more quickly and precisely identify ways to improve future profits or avoid predictable losses.

We analogize DEB to a set of eyeglasses that correct poor eyesight under SEB – see Figure 2. Absent eyeglasses, an entrepreneur’s vision of profit is blurry for individual transactions although he periodically sees the total profit clearly (Panel A) when he values his assets and debts. As a result, his memory of profit from individual past transactions is fuzzy. Panel B shows how eyeglasses sharpen the entrepreneur’s vision of the same transactions. Because the entrepreneur saw the past more clearly and can recall it better, he can predict more precisely future profits by product type and in total.

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11 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 or 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, pp. 339-340).
Basic DEB was expanded around 1550 CE to include revenue and expense accounts that labeled the sources of wealth changes arising from a transaction and split up the trial balance into the balance sheet and income statement. Thus, the expanded DEB journal entry for cattle and sheep would be:

<table>
<thead>
<tr>
<th>Account</th>
<th>Debit</th>
<th>Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep on Hand (DR)</td>
<td>$550</td>
<td></td>
</tr>
<tr>
<td>Cattle on Hand (CR)</td>
<td></td>
<td>$500</td>
</tr>
<tr>
<td>Cost of Goods Sold (DR)</td>
<td>$500</td>
<td></td>
</tr>
<tr>
<td>Revenue (CR)</td>
<td></td>
<td>$550</td>
</tr>
</tbody>
</table>

Littleton (1953, 27) argues that “income determination rather than determination of solvency has always been the central feature of double entry, the very heart and soul of the system, the *sine qua non.*” Ijiri (1967, 102-105) coined the term “causal double-entry” to describe how expanded DEB helps merchants understand wealth changes and profit sources better than SEB. 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)*

DEB is beneficial because accountants mentally evaluate transactions differently under DEB than SEB. After a sale, SEB requires multiple bookkeepers to record how physical resources have changed – i.e., the cash increase and the inventory decrease. With DEB, one accountant tracks these same items, but must consider future contingencies before recording a journal entry. For example, can the customer return the product, and, if so, is he likely to do so? For a credit sale, is the customer likely to pay on time? If the firm has a future performance obligation, what are the likely future costs to fulfill the obligation? Thus, modern DEB requires that the accountant mentally simulate future scenarios to assess risks and uncertainties (Suddendorf and Corballis 2007; Seligman, Railton, Baumeister, and Sripada 2017), leading to a more prospective focus and improved discovery of future profit opportunities.
The ledger accounts under DEB with financial statements 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). Expanded 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 contribution and periodic income sources are routinely generated and are far easier to find with a DEB system.

We expect that DEB improves the discovery of future profit opportunities in two ways. First, DEB makes it easier for a merchant to distinguish modestly profitable products from those that generate modest losses. This helps the firm winnow out unprofitable products and invest in profitable ones to increase total profit. Second, DEB’s timely and accurate profit data allows a merchant to evaluate business experiments involving new products and easily determine whether the experiment was successful. Thus, DEB helps evaluate planned changes in both the scale and scope of a business.

IV. HYPOTHESIS AND PREDICTIONS

We hypothesize that DEB changed entrepreneurial perceptions of and thinking about economic exchange, the accounting practices used in estimating transaction-specific profits, and the scale and scope of organizations that used DEB. We discuss these predictions in this section.

At least three conditions are necessary for DEB to displace SEB in business practice. First, entrepreneurs must have easy access to DEB technology. The widespread availability of accounting schools and textbooks for how to build a DEB system might suffice as evidence. Second, entrepreneurs must potentially benefit from DEB analysis, for instance, because the firm anticipates transactions that entail more complex operations in product marketing, production, or delivery. Third, effective use of DEB requires a supportive environment. McCloskey (2016, 94) suggests that capitalism, which she labels “trade-tested betterment governed by profit,” depends on the broad acceptance of ideas that
encourage virtuous profit seeking by entrepreneurs. Thus, DEB can help entrepreneurs increase their profits, and is a complement to, not a substitute for, McCloskey’s Bourgeois Virtues.

Once these conditions were met, along with the availability of money, algebra, writing, and other necessary institutions (Littleton 1927), then DEB could begin to displace SEB. When all these institutions are in place, DEB will likely emerge, and then gradually displace SEB as firms become more complex. We predict that, when all these conditions are met, the first organizations to use DEB will be those that have greater future profit opportunities involving complex exchange.

The DEBITS=CREDITS constraint applied in recording transactions is the ultimate cause of later gains from DEB. Repeated application of DEB’s DEBITS=CREDITS constraint shifts transaction analysis from identifying and recording the immediate physical resource changes to evaluating future contingencies that affect wealth measurement and income recognition. For example, revenue recognition requires that the accountant evaluate whether the firm has actually received valuable consideration and has fulfilled its obligations to the buyer. This mental shift leads to considering future contingencies that are often ignored with SEB – e.g., in a credit sale involving future product delivery, will the buyer be able to pay and will the firm be able to deliver the product?

We hypothesize that a micro-level consequence of the mental shift to a prospective focus under DEB (along with DEB’s flexibility to use accounts segregated by product type) is better tracking of profits from different products in real time. A corollary effect is that entrepreneurs will respond more quickly to price signals by changing their mix of goods and services – i.e., DEB will strengthen the feedback from product and factor markets to operating decisions. These decisions will, all else equal, lead to higher profits because the firm’s scale and scope can be more finely tuned using the faster DEB feedback. Aggregating across firms, expanded use of DEB will increase the productivity of firms using DEB and the industries in which they operate, increasing macro-economic efficiency and wealth.
V. THE EFFECT OF DOUBLE-ENTRY BOOKKEEPING ON TRANSACTION ANALYSIS

Transaction analysis plays a key role in the co-evolution of bookkeeping and economic exchange. We argued that DEB records help merchants better identify how the firm earns profits from different activities, which influences their future transactions. In this section, we discuss how (1) DEB’s DEBITS= CREDITS constraint exposes a demand for accounting concepts, (2) repeated use of DEB-based transaction analysis strengthens feedback within a mental model of profitable exchange, and (3) DEB-based transaction analysis can influence how the human brain perceives an economic exchange.

DEBITS=CREDITS and the Demand for Conceptual Accounting Knowledge

The DEBITS = CREDITS constraint of DEB fundamentally alters transaction analysis. Ijiri (1975, 84) explains how the DEBITS = CREDITS constraint leads the DEB accountant to see an exchange 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 an arithmetical view in SEB that counts and records what comes in or goes out to an algebraic perspective in DEB that imposes an equation that must always balance, so that changing any account requires an instantaneous offsetting change.12

12 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. Algebraic reasoning is much harder than arithmetic, which likely explains why so many first-time accounting students find DEB difficult and unintuitive.
Schelling (1995) argues that the DEBITS=CREDITS equation is not obvious *ex ante* but with careful definition seems obvious *ex post* (see also Jensen, 1983). 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. But since medieval markets were imperfect, perhaps some other mechanism led to equal-valued exchanges being observed routinely. In medieval Italy, religious prohibitions on usury caused an emphasis on “just” exchanges, where both sides received exactly their dues. Regardless of its cause, the immediate effect of DEB was careful definition of the residual difference between asset values, and this seemingly minor shift induced a fundamental change in transaction analysis.

Transaction analysis is complex even under basic DEB because requiring 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 separate amounts be recorded with a credit to owner’s equity to balance the entry? If a gain on purchase is not permitted (why?), which of the three values should be adjusted to make the debits and credits balance, and why?

After nominal *(income statement)* accounts were introduced, new questions arose 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, which evolved from accounting practice over centuries (Littleton 1933; Gilman 1939; Paton and Littleton 1940; Chatfield 1974). These questions are all intimately tied to
income determination at the transaction, product, and/or the firm level, but arise in recording a journal entry even under basic DEB.

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 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 “may be said to be coercive and self-executory” because they “must be obeyed if in the long run the enterprise is to survive.”

General accounting principles have evolved in practice over several centuries. These principles were induced from accounting practice in legal cases and accounting theory textbooks (Chatfield 1974; Baskin and Miranti 1997; Previts and Merino 1998). Auditing firms that observe and evaluate 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 been the product of ecological rather than constructivist rationality (Smith 2003; Waymire and Basu 2007, 94-104).

Two points about evolved accounting principles are important for present purposes. One is that modern accounting principles, especially those related to revenue and expense recognition, essentially assume that financial statement preparers use DEB. We infer this because SEB does not measure income for individual transactions – i.e., income is measured if and when the books are closed, and net assets are appraised. Second, the demand for conceptual knowledge underlying accounting principles increases when an entrepreneur plans and completes complex transactions. Thus, the speed of
accounting evolution is tied to that of exchange evolution. Had all transactions been cash-based and settled quickly, the accounting rulebook would be a brief pamphlet rather than a multi-volume treatise.

Textbooks and curricula in abaco schools emerged to store and diffuse the growing conceptual accounting knowledge. Thus, a bookkeeper who learned DEB in 1500 AD using Pacioli’s *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 enables future generations to deal with even more complex transactions; accounting practice could co-evolve with economic exchange in “ratchets” up to higher knowledge scaffolds (Tomasello 1999, 37).

DEB Strengthens Feedback Loops in Mental Models of Exchange

Accounting practice and economic exchange co-evolve with the mental perspective of entrepreneurs through repeated transaction analysis. Ijiri (1993, 281) suggests that the observation of many similar transactions affects how accounts are initially identified:

“For assets and liabilities to be expressible and their net changes to be explainable in accounts and amounts, there must be a highly-sophisticated system of classification and measurement both on the assets and liabilities and on the explanations for their net changes. There must be repetitive patterns that occur so frequently that people can recognize them by a short-hand explanation called an “account.” (emphasis added)

Repeated DEB-based transaction analysis helps shape a deliberative profit-focused mindset. We define a mental model as a symbolic representation that imperfectly captures some crucial aspects

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13 Unlike most other species, humans have developed a large capacity for social learning using culturally stored and transmitted knowledge in addition to individual learning, which lets humans thrive in virtually all climatic regions on earth (Boyd, Richerson, and Henrich 2011).

14 Parsons (1928, 651) asserts that the “spirit of capitalism is the leading concept of Sombart’s work” under which “everything else is to be understood,” and that this capitalistic spirit emphasizes that the “making of profit becomes an end which dominates the whole system” (Parsons 1928, 649). Sombart’s capitalist also has a sense of “business ethics whose typical virtues are reliability, temperance, frugality, industry, and thrift” (Parsons 1928, 650), which presage the Bourgeois virtues described by McCloskey (2006) nearly a century later. These virtues were necessary to promote the “business morality” and “commercial honesty” seen as necessary for business profitability (Sombart 1915, 121-122).
of real-life events and interactions (Johnson-Laird, 1983, 2010). For example, a mental model of our solar system could consist of several marbles revolving around a basketball. Craik (1943, 61) adds:

“If the organism carries a ‘a small-scale model’ of external reality and of its own possible actions within its head, it is able to 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.”

People iteratively construct mental models by analogizing from their experience in a base domain to a different target domain where they have less experience (Collins and Gentner 1987, 245-8). People simulate what they already do in novel imaginary situations, and this learning from experience induces cognitive change (Johnson-Laird 2013, 132-5). The mental model helps distinguish “signal” from “noise” in settings where search requires prediction (Filipowicz, Anderson, and Danckert 2016).

We propose that mental models of economic exchange differ when DEB is used rather than SEB. Consider a $15 cash sale of an item that had cost the seller $10. This transaction has two easily observed effects: a one-unit inventory decrease and a $15 cash increase. SEB bookkeepers likely will record only these superficial effects since SEB tracks physical units. The heart of DEB (i.e., DEBITS=CREDITS) impels the accountant to measure the value change from each transaction using known facts (e.g. who, what, where, when, why, how, and prices). Precisely measuring the gain or loss after each transaction helps identify profitable prospects before planning or entering new transactions.

Figure 3 depicts differences in the mental model of profitable exchange under DEB and SEB. Any unexpected profit from selling an existing product (Product 1) signals changed consumer demand. The merchant evaluates expected future profit by jointly evaluating current accounting profit and other market data (e.g., what buyers said to the merchant). The resulting mental profit estimate guides the entrepreneur’s product offerings and pricing choices. Figure 3 depicts the feedback loop as being

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15 A closely-related concept is that of a schema that comprises knowledge representing “objects or events” that “provide default assumptions about their characteristics, relationships, and entailments under conditions of incomplete information” (DiMaggio 1997, 269; see also Bartlett 1932, 300-14).
weaker under SEB than under DEB using dashed (bold) lines from accounting profit to the market signal for SEB (DEB) in Panel A (Panel B).

If the profit for a given product increases enough, the entrepreneur may expand production or develop new related products. A lower profit signals less product demand, which may require product improvements. In extreme cases, an entrepreneur may even consider introducing new products. If feasible product improvements will not restore demand, then exit might be the best choice.

**DEB and the Human Brain’s Evaluation of Exchange**

The repeated use of DEB is likely to alter connections between brain cells. Hayek (1952, 123-4) suggests that mental models are represented in the connections between neurons and their patterns of interaction within the brain:

“The adaptive and purposive behavior of the organism is accounted for by the existence of the ‘model’ of the environment formed by the pattern of impulses in the nervous system. In so far as this model represents situations which might come about as the result of the existing external situation, this means that behavior will be guided by representations of the consequences to be expected from different kinds of behavior. If the model can preform or predict the effects of different courses of action, and pre-select among the effects of alternative courses those which in the existing state of the organism are ‘desirable,’ there is no reason why it should not also be capable of directing the organism towards the particular course of action which has thus been ‘mapped out’ for it.”

Neuronal 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 brain is “plastic.” 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 predict that using DEB will cause similar effects in accountants, e.g., enlarged brain regions with stronger connections in processing rewards, sacrifices/pain, quantification, and social cognition.

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16 In considering new products, an entrepreneur is likely to first consider options that complement existing product lines or build off existing expertise – e.g., a restaurateur might consider offering catering of meals already sold in the restaurant. That is, innovations would most likely represent the “adjacent possible” (Johnson 2010).
Specialized neurons fire in response to different stimuli (e.g. sight, sound) and send signals to specialized brain regions for processing. Repeated coincidental firing of brain neurons causes stronger neuronal connections or as Shatz (1992, 64) says, “neurons that fire together, wire together.” These stronger neuronal connections lead to longer-lasting changes in memory and experiential learning (Rosenzweig, Bennett, and Diamond 1972; Quartz and Sejnowski 1997; Doidge 2007).  

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. Mental accounting occurs in many brain regions (Farrell, Goh, and White 2014; Eskenazi, Hartmann, and Rietdijk 2016). Thus, repeated DEB-based transaction analysis will likely implicate multiple memory functions that are 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 argue that an integrated mental model of profitable exchange includes an understanding that current expenditure usually precedes future revenue and profit. This model uses future-oriented thinking insofar as an entrepreneur evaluates profit implications before expending resources. In this sense, the model depicted in Panel B of Figure 3 uses the sharper vision that results from using DEB that we depicted in Panel B of Figure 2. That is, because DEB always matches direct past expenditures to current sales, it elicits prospective analysis of future profit consequences before current expenditures.  

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17 Buonomano and Merzenich (1998, 154) note: “For neurons to implement Hebb’s rule, they must possess a coincidence detector that records the co-concurrence of pre- and postsynaptic (or very rapidly successive) activity.” The human brain and DEB are consilient in that DEB records coincident changes in multiple accounts that are linked explicitly through cross-reference.

18 Consistent with complementary functional connectedness, brain connectivity changes for (formerly) illiterate adults as they first learn to read. For example, Skeide et al. (2017, 4-5) report that “six months of learning to read leads to massive macroscopic functional reorganization processes in the human brain... suggesting that literacy experience reshapes the earliest visual computation centers even before reaching the primary visual cortex.”
We expect that the DEB-based mental model will lead an accountant-entrepreneur to better understand how operational changes might alter future profits. For example, a DEB-based mental model would enable more accurate forecasts of how sales and costs would change if a durable goods producer offers a new warranty. A DEB-based mental model focused on future profit will better understand the “value chain” that makes a product desirable. This mental model will help decide better whether to change a product element or to expand into markets for complementary products.

VI. WEALTH GENERATION AND DEB-BASED MARKET STRATEGIES

Adam Smith (1776, Book 4, Chapter 2) observes that merchants’ profit seeking increases societal welfare:

“(I)t is only for the sake of profit that any man employs a capital in the support of industry; and he will always, therefore, endeavor to employ it in the support of that industry of which the produce is likely to be of the greatest value, or to exchange for the greatest quantity either of money or of other goods.

But the annual revenue of every society is always precisely equal to the exchangeable value of the whole annual produce of its industry, or rather is precisely the same thing with that exchangeable value. As every individual, therefore, endeavors as much as he can both to employ his capital in the support of domestic industry, and so to direct that industry that its produce may be of the greatest value; every individual necessarily labors to render the annual revenue of the society as great as he can. He generally, indeed, neither intends to promote the public interest, nor knows how much he is promoting it. By preferring the support of domestic to that of foreign industry, he intends only his own security; and by directing that industry in such a manner as its produce may be of the greatest value, he intends only his own gain, and he is in this, as in many other cases, led by an invisible hand to promote an end which was no part of his intention.”

Adam Smith’s emphasis on merchants’ profit motive raises an intriguing question: Since the “profit” from a transaction is not known *ex ante* but has to be discovered, does widespread use of DEB lead to better profit discovery and greater wealth creation? We analyze this issue in the current section.
DEB, Exchange Guidance, and the Scale and Scope of Business Organizations

Profit-seeking entrepreneurs change the scale and scope of firms and unintentionally increase societal welfare. Smith (1776, Book 1, Chapter 2) reminds us that it is “not from the benevolence of the butcher, the brewer, or the baker that we expect our dinner, but from their regard to their own interest.” Stated differently, a filet mignon reaches our table because a butcher stocked prime steaks in expectation of earning a profit. But how did the butcher choose what inventory to carry?

This process begins when the butcher asks himself: “Will customers pay enough for high quality steaks to yield me a profit?” We argue that the butcher will answer more accurately if he uses DEB. If he hears rumors that his customers want specific cuts of meat, he can more quickly check if he sold more of those cuts recently. That is, he could “simulate” his customers’ demand more accurately because he could easily access both price and quantity data on sales with DEB but only the latter with SEB. However, Smith’s artisanal butcher would likely not benefit much from DEB unless he expanded his firm.

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

U.S. meatpackers were managed using cost estimates. Bliss (1922, 290) notes:

“The fact that the markets for livestock and packing-house products are unusually sensitive means that those controlling packing-house operations must be promptly and well supplied with market information and cost statistics. They must have at hand at all times the most recent information as to the markets and costs of live animals; they must know what the

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19 High common costs made it difficult to assign unique costs to the primary product and by-products (Greer 1937). 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 1937).
products are selling for, wherever such products are marketed; and must have up-to-the-minute and reliable information as to costs.”

These cost-finding systems were built using DEB, which could easily classify different costs used in managerial decisions (Garcke and Fells 1889, 4-11; Hawkins 1905, 1-10; Gilman 1911, 249).

Nineteenth-century meatpackers might earn only slightly higher profits with DEB because their growth options were limited. Thus, using DEB rather than SEB would hardly change any transaction’s profit. But this small effect for one transaction scales up for a firm with thousands of transactions and is much larger if we add profit changes across firms worldwide. In other words, DEB may have a large aggregate effect even though it is neither necessary nor sufficient for any firm to be profitable.

These long-term effects were likely not anticipated by the inventors of basic DEB just as Steve Jobs did not predict most uses of his iPhone. Nor can modern educators easily perceive DEB’s effects. Because DEB has a small effect for any given exchange, we (present authors included) tend to focus on the more obvious calculation check that DEB provides. Once economies switch to DEB, we do not see their counterfactual performance under SEB. Merchants are not likely aware of the different choices they would have made under SEB, and thus, cannot evaluate the opportunity cost of using DEB.

DEB, Entrepreneurial Alertness, and Strategic Flexibility in Large Organizations

Our analysis suggests that strategic flexibility is increased by use of DEB. In this sense, a DEB-based mental model helps “alert” entrepreneurs discover profits (Kirzner 1973, 223). Hayek (1968, 181-2) elaborates upon this idea:

“Utilization of knowledge widely dispersed in a society with extensive division of labor cannot rest on individuals knowing all the particular uses to which well-known things in their individual environment might be put. Prices direct their attention to what is worth finding out about market offers for various things and services.... The knowledge of which I speak consists rather of a capacity to find out particular circumstances, which becomes effective only if possessors of this knowledge

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20 Such data would be important for the choice to sell a calf as veal instead of growing it to full size. Later in this section, we discuss several historical examples of DEB-based accounting data use by managers. Bliss (1924) describes use of accounting data by early 20th century managers in considerable depth.
are informed by the market which kinds of things and services are wanted, and how urgently they are wanted.”

In our story, an entrepreneur reacts to price changes only when they inform him of changed profit opportunities. In Hayek’s words, entrepreneurs “direct their attention” to discovering whether local price changes can improve their profit prospects with suitable operational changes. The entrepreneur considers all easily available data. We contend that these evaluations and responses will be more effective on average when the entrepreneur uses DEB to obtain precise and timely data on prior profitable choices that can guide future exchange decisions (Waymire 2009). Consequently, in DEB-based economies, there will be fewer unexploited Pareto-improving trades that Schelling (1995, 22) describes as “free lunches all over waiting to be discovered or created.”

A single merchant using DEB (unlike his competitors) within a competitive discovery process (Hayek 1968, 181) can sell products at lower margins. In the short-run, this will likely lead to greater product market share and higher total profits. Competitors using SEB will likely lose by a small amount on average if they try to compete head on. If SEB firms can locate market niches for unique goods, they can survive. Similarly, a firm insulated from market competition by government-granted monopoly could survive using SEB. One such case is the Dutch East India Company cited by Yamey (1964, 126-130). Like any management tool, effective use of DEB generates higher volume and profit, and leads 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 skewed profitability and firm size, consistent with our hypothesized advantage from assessing profit contributions quickly (Bessen, 2017).

Additional Historical Examples

Many examples beyond the 19th century meatpacking industry suggest that large gains can be earned by using DEB to more accurately discover profits from different transactions. An early example are the segregated accounts used by the Venetians to track profits in different foreign trading ventures
during the 15th century (Pacioli (1494/1915, Ch. 20), and the similar use of venture accounting by pre-1800 English merchants (Winjum 1970; 1972).  

Francesco Datini, a 14th century Tuscan merchant, is another example (Origo 1957/1986). Datini accumulated hundreds of DEB account books and ledgers during his career from 1350 to 1410 (Origo 1957/1986, 107-115) that have survived to the present. He 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) highlights 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).  

Another example is Andrew Carnegie, a 19th century steel magnate who used detailed DEB-based cost accounting systems.  

Carnegie’s motto was “watch the costs and the profits will take care of themselves.” A superior knowledge of costs let Carnegie undercut the competition by bidding better for large jobs and helped Carnegie Steel dominate the U.S. steel industry (Johnson and Kaplan 1987, 32-34). Other entrepreneurs who learned DEB when young include German banker Jacob Fugger (1459-1525) and American industrialist John Rockefeller (1839-1937) (Steinmetz 2015, 10; Parr 2016).  

Since firms could survive without using DEB, especially if the economic environment was turbulent (Yamey 2000) or if transactional complexity were static, the technique was slow to be used.

21 Yamey (2000, 2) argues that separate accounts for ventures could be and were kept under SEB too, although many accounting authors in the Middle Ages regarded separate accounts as characteristic of DEB.  
22 The partnership agreement in place even before Carnegie’s involvement stipulated the use of DEB at Carnegie Steel (Bridge 1903, 5-8). Carnegie took a night-school class on DEB at age 20 because “all the great firms kept their books in double entry” (Carnegie 1920, 36).  
23 Sam Walton used profit data (presumably based on a DEB system) in managing the Ben Franklin “five and dime” store where he began his business career. This system 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 further notes, “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 starting breaking their rules on everything else. I even used it for the first five or six Wal-Marts” (Walton 1992, 30-1).
adopted. This likely accounts, in part, for why the effect of DEB on entrepreneurial behavior and mental attitudes could have diffused gradually.\(^{24}\) Nonetheless, we predict that (1) firms that adopted DEB earlier earned greater profits, and (2) the spread of DEB beyond Renaissance Italy led to increased wealth. The long-run effect is a co-evolution of DEB with mental models of exchange and the complexity of economic exchange that generated economic gains.\(^{25}\)

**VII. IMPLICATIONS FOR FUTURE EMPIRICAL RESEARCH**

We theorize about the emergence and spread of DEB as part of a co-evolutionary process that affects both the process of transaction analysis and the magnitude and source of gains from economic exchange. We discuss potential empirical tests of these two consequences of DEB in this section.

*Research on DEB-Based Transaction Analysis*

Researchers should study how DEB changes transaction analysis. Process-tracing techniques could be used to identify how experienced accountants analyze transactions (Ford et al. 1989). For example, how do accountants change the journal entry for sales revenue as future collection becomes more uncertain? Where do they begin this analysis? Do they start from previous cases or do they start with more basic notions of uncertainty and risk? Is this process affected by a history of interaction between the customer and the firm? How do accounting concepts affect transaction analysis? For instance, does an accountant analyze a complex sales transaction differently after being prompted to

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\(^{24}\) DEB was not used regularly to produce income statements for the entire firm until the 19\textsuperscript{th} century (Yamey 1949; 1964). Thus, the early use of DEB to measure net contribution suggests that the first uses of DEB-induced discovery processes were likely at the individual transaction level and were only later extended to higher levels. This is consistent with Sombart’s (1915, 120) assertion that capitalism took a long time to emerge.

\(^{25}\) 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 Isaac Newton, Antoine Lavoisier and Benjamin Franklin who all likely used DEB professionally and discovered conservation laws for angular momentum (Newton), atomic mass (Lavoisier) and electrical charge (Franklin).
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)?

Another important research question is how DEB changes entrepreneurs’ mental models. We predict that DEB experience helps a merchant better identify conditions where a small positive profit is more likely than a small loss and more accurately forecast overall profits and its components. The higher quality DEB data will likely lead to better strategic decisions in response to environmental changes.

A two-part laboratory experiment could test these predictions. A first task could have both accountants and non-accountants analyze a series of transactions and forecast future profits. A second task would be to trade in a laboratory market with uncertain payoffs where subjects received either DEB or SEB data. We expect that an individual’s payoffs will reflect their ability demonstrated in the first stage transaction analysis and the quality of data they received during the experimental game.

Researchers can also study how accountants internalize DEB by tracking changes in student brains during their first DEB course. We envision an approach akin to Nutley, Darki and Klingberg (2014), who track whether children learning a musical instrument increase working memory, reasoning effectiveness, and gray matter volume in two brain regions known to be involved in reading music. This research would let us see which brain regions change while students learn DEB. Are these regions used in quantification, reward processing and social cognition? Do students with high grades have greater brain changes and/or did they have larger brain regions useful for accounting when they start out?

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26 Dickhaut, Basu, McCabe, and Waymire (2010) and Birnberg and Ganguly (2012) discuss the prospects for neuroscientific accounting research more generally.
Research on the Impact of DEB on Wealth Generated by Economic Exchange

We pose two questions to guide future research on the economic consequences of DEB. First, in an economy with easy access to DEB, which firms and industries will implement DEB first? Second, does the introduction of DEB into an economy increase realized gains from exchange?

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. 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.

Our second research question is whether DEB leads to greater realized gains from exchange. We suggest two ways to explore this critical issue. One route is to examine changes in competitive dynamics within an industry when one or more firms gains access to DEB-based information. 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. We could then explore how wealth generation changes when more agents use DEB. This could then be extended by tweaking the magnitude of possible gains from exchange, the complexity of exchanges, and the personal cost to implementing DEB. Collectively, evidence from this agent-based simulation would provide evidence on DEB’s survival value compared to SEB.

A final research opportunity is to study whether the geographical diffusion of DEB to countries beyond Italy was 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. We can then test for macroeconomic performance improvements following DEB introduction dates, although we have to remember that expanded DEB was more likely to have been transferred at later dates (e.g. 19th century Japan).

VIII. CONCLUDING REMARKS

We theorized about why single-entry bookkeeping (SEB) was displaced by double-entry bookkeeping (DEB) in 13th century Italy and beyond. We focused on two issues. The first is how DEB provided benefits that could not be obtained with SEB (or obtained only at higher cost). The second question deals with the effects of DEB that would not have resulted if SEB had continued to be used.

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27 Databases have been developed that track the presence of a cultural trait in a specific country or region. These include the Standard Cross-Cultural Sample (SCCS) used to testing for a relation between the complexity of recordkeeping in a society and the extent to which other institutions had generated beneficial exchange (Basu, Kirk, and Waymire 2009). A similar, but more extensive, database with coded accounting-like variables is the Human Relations Area Files (HRAF). The HRAF includes a variable measuring the presence of DEB in a society.
Our theory concerns the co-evolution of mental models of exchange having a greater emphasis on prospection and the discovery of more profitable forms of exchange that increase wealth as the technology of DEB spreads across place and time. We hypothesize that DEB induced a shift towards future-oriented thinking where entrepreneurs used more timely DEB profit information to identify the wealth implications of transactions before they are consummated. As a result, DEB-based information could better guide a profit discovery process focused on what Kirzner (1973, 222-30) describes as heightened entrepreneurial “alertness” to profit opportunities. This discovery process is co-evolutionary in that improvements in accounting technology depend on the ability of entrepreneurs to conceive of and implement new forms of profitable exchange.28

Any theory seeking to explain the evolution of a human trait or a cultural practice must address four questions posed by Tinbergen (1963). We frame Tinbergen’s four questions for DEB, which is an evolved cultural practice, using recent research (Nesse 2013; Bateson and Laland 2013). The four evolutionary questions pertinent to DEB are: (1) How does DEB alter the cognition and behavior of individuals and the organizations within which they work? (Development) (2) What is the longer history of DEB in terms of spreading to other firms and societies? (Long-Run History) (3) By what means does DEB accomplish some functional purpose? (Mechanism) (4) How have changes to DEB interacted with the environment to influence the survival of organizations in ways that can help explain why DEB is widely-used? (Adaptive Significance)

Table 2 summarizes the answers to these questions that we propose in this paper. The development aspect of DEB emerges at the micro level from the experience of individuals whose perceptions of profit are shaped differently under DEB and SEB. These micro-level effects of DEB include prospective mental models of profit, an increased demand for accounting principles to improve profit

28 DEB is one part of the culture that fosters economic exchange by organizations, and the benefits of DEB manifest through multiplier effects arising from behaviors that are adaptive in evolutionary terms (Wilson 1980, chapters 2 and 26).
estimation at the transaction level, and neural connections within accountants’ brains that grow stronger as accountants learn and implement DEB in practice. The long-run history of DEB is how it spread over time through means for storing and transmitting knowledge (e.g., textbooks and accounting schools). The primary mechanism through which DEB operates is the more rapid reckoning of profit that results from DEB’s requirement that DEBITS=CREDITS and the ultimate adaptive significance of DEB lies in the enhanced survival of organizations that use DEB to guide economic exchange.

Our perspective on DEB is dualistic like that of Ijiri (2005). First, DEB measures profit contribution from past transactions, but one of its main consequences is the more effective mental discovery of future profit opportunities. A second duality is that the collective benefits of DEB could be huge but go unnoticed because they accrue in small increments over many transactions. Thus, DEB could be like a “vein of water flowing hidden underground, secretly making the ground green” (Carlyle 1888, volume VI, 107) that could have had large unrecognized impact on economic performance.

Our analysis suggests at least two hard-to-recognize positive effects of DEB. First, transaction analysis takes place in the accountant’s mind, which a researcher cannot directly observe. We argue that DEB transforms transaction analysis because the DEBITS=CREDITS constraint compels the consideration of future contingencies that are central to initial valuation and profit measurement. Second, consistent DEB use affects a company’s profit in the context of a longer-term co-evolution of accounting practice, thinking about economic exchange, and profitability from economic exchange. Thus, it will be very difficult to parse out the unique effect of DEB on the wealth of firms and societies – i.e., “endogeneity” will be omnipresent in naturally occurring data. Designing laboratory experiments to address this key issue 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.

We do not expect that all of our hypotheses will be supported and hope that researchers will articulate an even richer theoretical perspective. Scholars like A.C. Littleton and Yuji Ijiri took major
steps toward explaining the importance of DEB, and it is high time that accounting researchers returned
to this foundational question, if only to put our conceptual frameworks and textbooks on firmer ground.

The next research steps 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 perceived knowledge is overestimated (Merton 1936; Hayek 1945). Empirical evidence
suggesting that accounting data properties have changed fundamentally in recent decades (Basu 1997;
Dichev and Tang 2008; Bushman, Lerman, and Zhang 2016) supports 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 and not in reporting to external “stakeholders” is a worthy objective.

As a discipline, we should offer a coherent answer to the student who asks: why is DEB used by
most big firms worldwide? Hatfield (1924, 253) suggested at least a partial answer when he tried to
remove the social stigma attached to double-entry bookkeeping:

“(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?”

If we can together develop a coherent theory to explain why DEB is important, we might attain
greater respect as an academic discipline (cf. Demski 2007). At worst, future entrepreneurs would better
understand why learning DEB is important for their success, and that too would be a favorable outcome.
REFERENCES


Littleton, A. C., 1933. *Accounting Evolution to 1900*. American Institute Publishing Co.: New York, NY


Ympyn, J. C., 1547. *A Notable and very excellente woorke, expressying and declarying the maner and forme how to kepe a boke of accomptes or reconynges... Translated... out of Frenche into Englishe.* London, UK: Richard Grafton.


Table 1  
Characteristics of Accounting & Other Institutions from Recordkeeping to the Emergence of Modern DEB

<table>
<thead>
<tr>
<th>Type of Accounting</th>
<th>Recordkeeping</th>
<th>SEB</th>
<th>Early DEB</th>
<th>Modern DEB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>8,000 - 3,200 BCE</td>
<td>3,200 BCE - 1,200 CE</td>
<td>1,200 CE - 1,550 CE</td>
<td>&gt; 1,550 CE</td>
</tr>
</tbody>
</table>

A. Accounting Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Physical units</th>
<th>Physical units &amp; multiple currencies</th>
<th>Single currency</th>
<th>Single currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit of account</td>
<td>Clay tokens, knotted strings, notched sticks</td>
<td>Clay tablets, tally sticks, parchment</td>
<td>Parchment, paper</td>
<td>Paper, electronic records</td>
</tr>
<tr>
<td>Record format</td>
<td>Linked written records</td>
<td>Debits=Credits with real accounts</td>
<td>+ Nominal accounts</td>
<td></td>
</tr>
<tr>
<td>Record content</td>
<td>5 Ws included piecemeal</td>
<td>Asset &amp; debt list</td>
<td>Trial balance</td>
<td>+ Income Statement</td>
</tr>
<tr>
<td>Financial statements</td>
<td>None</td>
<td>Asset &amp; debt list</td>
<td>Trial balance</td>
<td>+ Income Statement</td>
</tr>
</tbody>
</table>

B. Exchange

<table>
<thead>
<tr>
<th>Exchange mode</th>
<th>Gift, Barter</th>
<th>+ Monetary</th>
<th>Mainly monetary</th>
<th>Monetary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markets</td>
<td>Local/Regional</td>
<td>National</td>
<td>Continental</td>
<td>Global</td>
</tr>
<tr>
<td>Largest Urban Population</td>
<td>15,000</td>
<td>1,000,000</td>
<td>1,000,000</td>
<td>30,000,000</td>
</tr>
</tbody>
</table>

C. Production

<table>
<thead>
<tr>
<th>Food Production</th>
<th>Animal domestication and agriculture</th>
<th>Terraced farming, irrigation</th>
<th>Mechanized farming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other manufacturing</td>
<td>Pottery &amp; weaving</td>
<td>Copper/bronze &amp; small-scale manufacturing</td>
<td>Artisanal production &amp; putting-out system</td>
</tr>
</tbody>
</table>

D. Credit

<table>
<thead>
<tr>
<th>Extended to</th>
<th>Family</th>
<th>Kin group</th>
<th>Acquaintances</th>
<th>Strangers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>Harvest cycle</td>
<td>Annual</td>
<td>Multi-year</td>
<td>Long-term</td>
</tr>
</tbody>
</table>

E. Law & Organizations

<table>
<thead>
<tr>
<th>Property Rights</th>
<th>Transition to individual</th>
<th>Individual</th>
<th>Individual</th>
<th>Individual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organization Form</td>
<td>Sole proprietorship</td>
<td>+ Partnership</td>
<td>+ Guild, corporation</td>
<td>Joint stock company</td>
</tr>
</tbody>
</table>

F. Mode of Thinking

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Harvest cycle</th>
<th>Annual</th>
<th>Multi-year</th>
<th>Long-term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causal Reasoning</td>
<td>Indirect</td>
<td>Abstract</td>
<td>Hidden</td>
<td>Extended</td>
</tr>
<tr>
<td>Number system</td>
<td>1-1</td>
<td>Cardinal</td>
<td>Ratio</td>
<td>Integer</td>
</tr>
<tr>
<td>Calculation tools</td>
<td>Counting board, abacus</td>
<td>Slide rule, electronic computing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2
Tinbergen’s Four Questions Framework Applied to Double-Entry Bookkeeping (DEB)

<table>
<thead>
<tr>
<th>Two Kinds of Explanation</th>
<th>Two Objects of Explanation</th>
<th>Form (Current Features of DEB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Proximate</strong></td>
<td>Development/Historical (Sequence that Results in DEB)</td>
<td></td>
</tr>
<tr>
<td>What causes an individual and organization to use DEB?</td>
<td>DEVELOPMENT Q: How does DEB develop in individuals &amp; organizations?</td>
<td>MECHANISM Q: How does DEB work to achieve some functional purpose?</td>
</tr>
<tr>
<td></td>
<td>A: As individuals are exposed to DEB via education &amp; experience, their mental perspective on economic exchange becomes more focused on profit from economic exchange &amp; its sources.</td>
<td>A: DEB is built from a foundation where profit from an individual transaction is immediately reckoned in order to fulfill the DEBITS=CREDITS constraint.</td>
</tr>
<tr>
<td><strong>Ultimate</strong></td>
<td>Development/Historical (Sequence that Results in DEB)</td>
<td></td>
</tr>
<tr>
<td>How have the form and function of DEB been influenced by evolution?</td>
<td>LONG-RUN HISTORY Q: What is the history of DEB in improving on its predecessor forms of accounting?</td>
<td>ADAPTIVE SIGNIFICANCE Q: How does DEB improve the welfare &amp; survival prospects of individuals and organizations that use it?</td>
</tr>
<tr>
<td></td>
<td>A: Increased geographical diffusion of DEB over time as knowledge storage improves.</td>
<td>A: DEB enhances discovery of net gains from new forms of exchange and improves the survival prospects of organizations that use it.</td>
</tr>
</tbody>
</table>

This table applies Tinbergen’s four questions to Double-Entry Bookkeeping (DEB). These questions and their formatting in this table are based primarily on Nesse (2013) and secondarily on Bateson and Laland (2013) and Tinbergen (1963).
Figure 1
Structure of Single Entry Bookkeeping records in the Zenon papyri (estate records in middle of the 3rd century BCE in Ptolemaic Egypt) reconstructed based on Grier (1932)

Zeno’s records for the estate he managed for Appolonius in the Fayûm (Egypt) in the middle of the 3rd century B.C. (more than 1,000 papyri)

- General accounts (monthly, annual)
  - Argyrikoi logoi (money-accounts)
  - Sitikoi logoi (grain-accounts)
  - Cash
  - Livestock
  - Grain
  - Others

- Ephemerides (Ledgers balanced daily or 2-3 days)
Figure 2
Clarity of Past & Future Profitability with Single- vs. Double-Entry Accounting for a Two-Product Firm

A: SINGLE-ENTRY

*Current Transactions by Product Type & Profitability*

<table>
<thead>
<tr>
<th>Profit Transactions</th>
<th>Total Profit</th>
<th>Expected Future Profitability by Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Loss Transactions    |              |                                               |

B: DOUBLE-ENTRY

*Current Transactions by Product Type & Profitability*

<table>
<thead>
<tr>
<th>Profit Transactions</th>
<th>Total Profit</th>
<th>Expected Future Profitability by Product Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Loss Transactions    |              |                                               |
Figure 3
Feedback from Accounting Profits in Exchange Evaluation Under SEB and DEB

A: SEB-BASED EVALUATION (Weaker Feedback)

Product 1
Design, Production, Marketing, & Service Choices

MARKET SIGNAL
\( \Delta \text{PROFIT} > 0 \) Expand?
\( \Delta \text{PROFIT} < 0 \) Exit?

Evaluation of Future Exchanges

Product 2
Design, Production, Marketing, & Service Decisions

B: DEB-BASED EVALUATION (Stronger Feedback)

Product 1
Design, Production, Marketing, & Service Choices

MARKET SIGNAL
\( \Delta \text{PROFIT} > 0 \) Expand?
\( \Delta \text{PROFIT} < 0 \) Exit?

Evaluation of Future Exchanges

Product 2
Design, Production, Marketing, & Service Decisions