**The Evolution of Double-Entry Bookkeeping**

by

Sudipta Basu
(Temple University)

and

Gregory Waymire
(Emory University and Chapman University)

September 7, 2020

We thank two anonymous referees, Patty Dechow, Deirdre McCloskey, Karl Schuhmacher, Alan Sangster, Matt Sooy, Shyam Sunder, Daniel Tinkelman, attendees at the Chapman Behavioral Finance Conference, Hawaii Accounting Research Conference and American Accounting Association annual meeting, and workshop/brownbag participants at several universities—Alaska (Economics), Emory, Oklahoma, Southern California, Temple and Yale—for helpful comments and suggestions.

**The Evolution of Double-Entry Bookkeeping**


**ABSTRACT**

Double-entry bookkeeping (DEB) slowly displaced single-entry bookkeeping (SEB) over 800 years and is now used by all but the smallest firms. We address three questions about DEB's evolution: (1) *What* is the main benefit of DEB? (2) *How* did DEB emerge and evolve? and (3) *Why* did individual firms and economies choose DEB over SEB? We hypothesize that DEB better measures the profits from individual transactions. The crucial innovation was the DEBITS=CREDITS constraint, which required an equity account to balance assets and liabilities that led to continuously updated cumulative profits. We argue that DEB improved firms' survival prospects by enabling more effective discovery of future profit opportunities. We suggest tests of our arguments about how and why DEB improved the functioning of firms and economies.



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

JEL Classification: M41, D23, D83, B15

"We make constant use of formulas, symbols and rules whose meaning we do not understand and through the use of which we avail ourselves of the assistance of knowledge which individually we do not possess. We have developed these practices and institutions by building upon habits and institutions which have proved successful in their own sphere and which have in turn become the foundation of the civilization we have built up."

*Friedrich Hayek* (1945, 528)

"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 Jensen* (1983, 330)

"(T)he real significance of double-entry bookkeeping compared to single-entry bookkeeping is not in the dual classification or the computational double-check (what a triviality!), but in the power of double-entry to make us look into the cause-and-effect relationships among the changes in the resources controlled by the entity."

*Yuji Ijiri* (1975, 84)

## I. INTRODUCTION

Double-entry bookkeeping (DEB) is used globally to record transactions and measure profits. Accounting scholars still do not really understand why DEB gradually replaced the previous single-entry bookkeeping (SEB). We aim to identify *what* DEB does better (function), *how* it improved over time (mechanism), and *why* it emerged and became dominant (adaptive significance), as needed for an evolutionary analysis of any evolved biological or cultural trait (Wilson 2017, 5-6). We briefly describe prior research on evolutionary causation as needed to frame our theory of DEB evolution.

DEB emerged from an unplanned and spontaneous evolutionary process that led to many uses that were initially unforeseen.[1] However, firms that customized DEB for their own purposes found fruitful new uses. *What* DEB initially did better than SEB was to organize transaction data. 13th century Florentine bankers found DEB valuable for tracking increases and decreases in specific borrower

[1] The Android operating system evolved similarly in that many future applications were not even imagined when Google introduced it in 2008, but in June 2020 there were nearly 3 million open-source apps in the Google Play store launched by individual developers.

accounts (Martinelli 1974; Sangster 2016). The better organized DEB records helped bankers and borrowers avoid the reputational costs of legal disputes (Pacioli 1494/1914, 1). The Genoese government was required by a 1327 AD law to follow bankers' DEB practices (Martinelli 1977, 13-14), likely because well-organized accounts help ensure that funds were spent on the designated purposes.

An evolved biological trait's function can change as that trait adapts to new environments. Gould and Vrba (1982) refer to such cases as "exaptations" and cite bird feathers, bones, mammal lactation, and DNA repetition as examples. Modern accounting is an institutional exaptation of DEB arising from firms' search to find better ways to compete (Byrne 1937). We theorize that *what* evolved DEB did better is to aid discovery of future profit opportunities, which multiplied as manufacturing and services became more specialized. Early examples of DEB profit tracking include the venture accounts used by both the 14th century Venetians and 16th century British firms in overseas trading ventures (Pacioli 1494/1914, ch. 20; Winjum 1970; 1971).

*How* did DEB evolve from better organizing transaction records for prudent risk management in the 13th century to measuring profits from complex transactions today? DEB's flexibility in application for a given firm has long been recognized.[2] We argue that the DEBITS=CREDITS constraint was the crucial mechanism driving innovation. Under SEB, transactions were often recorded in different physical units causing an "apples and oranges problem." In contrast, DEB requires that in any journal entry, the sum of debits equals the sum of credits as measured in a *single monetary unit of account*. 13th century DEB added equity accounts to the assets and liabilities used in single-entry bookkeeping (SEB), applying the balance sheet equation to continually accumulate data on retained earnings. 16th century DEB defined profit components such as revenue and expense to improve causal understanding of

[2] Littleton (1953, 45) attached great importance to the fact that DEB is adaptable to any firm: "Progress over the centuries in adopting account-categories to fit needed classifications of transaction data is a clear indication that accounting had quasi-statistical characteristics from its beginning – characteristics that were basic and yet flexible enough to be adaptable to conditions beyond the reach of the wildest imagination long ago."

performance (Littleton 1937, 19-20; Ijiri 1975, 80-84). The slow rise of cost accounting since the 16th century improved measurements further (Garcke and Fells 1889; Vatter 1950, 329-344; Garner 1954/1976, 2).

The balance sheet depicts the *state* of net resources owned by a firm and the income statement describes the *process* of how the firm's net resources position changed during a period (Simon 1962, 479). The income statement shows why net resources changed by aligning cost sacrifices (expenses) with rewards (revenues) in time (Ijiri 1975; 1981) using a common measurement unit. The income statement reveals *how* an entrepreneur can increase his wealth, which the balance sheet only reports. Repeated refinement of DEB revealed a latent demand for conceptual accounting knowledge to better understand how wealth changes (i.e., revenue and expense components) with every transaction.[3]

*Why* firms ultimately chose DEB is that economic competition "selects for" firms with positive profits (Byrne 1937, Alchian 1950). More timely profit evaluation under DEB provided better guidance than SEB for decisions about the scale, scope, and profitability of firms (Littleton 1933; Ijiri 1981).[4] Quicker profit measurement and analysis ensured that "fuller use will be made of the existing knowledge" of the firm (Hayek 1945, 521). Werner Sombart (1902) argued that DEB's main benefit lies in better profit measurement (Parsons 1928, 649) that furthered the expansion of capitalism. [5]

[3] We focus on organizations guided by profit motives. While "non-profit" organizations abound, this is often just a semantic difference. Thus, many governments have used DEB, and they would often be classified as "non-profit" even though their managers usually seek to control more economic resources.

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

[5] Like Sombart, Max Weber argued, according to Carruthers and Espeland (1991, 32): "Rational capital accounting, in conjunction with calculable law, rational technology (mechanization), free labor, and the commercialization of economic life, is, for Weber, an element in a general process of rationalization that is both a precursor to and the consequence of modern capitalism." Schumpeter (1950, 123) said that DEB was a "towering monument" of capitalism that turned "the unit of money into a tool of rational cost-profit calculations." Mises (1949, 231) suggested that DEB "makes success and failure, profit and loss ascertainable." Yamey (1949; 1964) argues contrarily that Sombart's proposition is not obvious since firm-wide income statements were produced only several centuries after DEB's first appearance.

Evolutionary change results from hard-to-observe forces that correlate with a firm's chances of survival in its environment (e.g. Alchian 1950; Price 1970, 1972; Waymire and Basu 2011). The main force in DEB evolution was likely selection insofar as SEB firms survived less often, perhaps because SEB firms could not expand successfully. Increased DEB use could also reflect changes due to transformation, such as when a SEB firm switches to DEB, perhaps because transaction records from a DEB system are preferred as evidence in legal disputes (Sangster 2016). As survival-enhancing uses of DEB were found, they spread as norms and did not perish with their discoverers (Sunder 2005). Migration occurs if new firms are more likely to use DEB than SEB – e.g., if more entrepreneurs learned DEB in trade school (Basu 2015). DEB use likely increased dramatically after Gutenberg's (1440) printing press made books such as Pacioli (1494) more affordable (Eisenstein 1979). We expect that DEB use increased after 1,800 AD as large manufacturers proliferated and used DEB in cost accounting (Garcke and Fells 1889, 4-11; Garner 1954/1976; Chandler 1977). By the early 20th century, most large firms routinely used DEB to produce financial reports like those of today (Hatfield 1909; Sivakumar and Waymire 1993).

DEB *co-evolved* with firms' transactions as better measurement of transaction profits improved identification of competitive advantages from firms' value and supply chains (Porter 1985). Stronger bi-directional links were built between accounting practice, the (unobserved) mental evaluation of possible exchanges by entrepreneurs, and the exchanges they executed (Basu and Waymire 2006; Dickhaut, Basu, McCabe, and Waymire 2010) – see Figure 1. DEB evolved as firms fit together firm-specific data structures by trial and error.[6] The bi-directional links got stronger as entrepreneurs learned from first-hand experience and spread this knowledge to others through conversations and written texts. Entrepreneurs' thinking would change even more as broad principles were discovered inductively (e.g. Paton and Littleton 1940) or deductively (e.g. FASB's Conceptual Framework Project).

[6] We expect that this "fitting together" process was spontaneous in the same way that common law evolved in Western societies during the Middle Ages (Rubin 1977; Berman 1983; Benson 1988).

We suggest several ways for empirical research to evaluate our evolutionary theory. These include surveys to identify why and when firms switch from SEB to DEB, archival studies that track how DEB spread worldwide and how DEB diffusion correlates with changes in macro-economic performance, and lab and field experiments that compare the economic gains from exchange produced by firms and economies that have access to DEB compared to settings where only SEB is available.

Two caveats are needed before proceeding. First, we do not seek to explain every twist and turn in DEB's history. DEB did not emerge fully formed and the first entrepreneurs who used DEB did not foresee its vast implications for future accounting evolution, just as eagle eyesight was not predictable from the first animals with light-sensitive spots. Second, we argue that DEB complemented other profit discovery tools such as a monetary economy and algebraic reasoning, i.e., DEB did not alone improve the economic performance of firms and economies, just as eagles need aerodynamic bodies, sharp claws and other evolved characteristics alongside their keen eyesight to be apex predators.

We first describe how DEB improved on SEB and how DEB evolved into modern accounting. We then discuss why firms chose DEB and why DEB proved advantageous in some environments. Lastly, we identify opportunities for future empirical research and then briefly conclude.

## II. *WHAT* DEB DID DIFFERENTLY THAN SEB AND *HOW* IT EMERGED AND EVOLVED

DEB systems record transactions differently than did SEB systems. We first present stylized entries under SEB and different DEB stages. We then use surviving records to describe their evolution.

If a firm sold a baseball bat originally costing $15 for 20 silver dollars, the sale would be recorded in a SEB system (possibly by separate bookkeepers for each commodity) as:

| | | | |
|---|---|---|---|
| Baseball bats | -1 | Silver Dollars | +20 |

The entry under early DEB for an arms-length sale of a baseball bat for $20 that originally cost $15 with a perpetual inventory system (before the introduction of income statement accounts) is:

| | | |
|---|---|---|
| Cash (Debit) | $20 | |
| Inventory (Credit) | | $15 |
| Owners' Equity (Credit) | | $ 5 |

The DEB entry under the DEBITS=CREDIT constraint assumes that the buyer and seller are exchanging items of equal value, which is a fair transaction in an active marketplace. The *single monetary unit of account* lets this constraint be checked. These assumptions permit profit recognition at the point of sale, which was difficult under SEB with incommensurate units.[7] Crucially, DEB requires a *single bookkeeper* to record dollar amounts for both sides of the transaction simultaneously with any difference attributed to equity, which facilitates internal controls.

Once income statement accounts were created, the same transaction would be entered as:

| | | |
|---|---|---|
| Cash (Debit) | $20 | |
| Revenue (Credit) | | $20 |
| Cost of Goods Sold (Debit) | $15 | |
| Inventory (Credit) | | $15 |

The change in owner's equity in early DEB is decomposed into revenue and expense that permits better understanding of the components of gross profit, and explicitly lets entrepreneurs examine the impact of changing costs or selling prices on profits. DEB was further modified by manufacturers to accumulate production costs in inventory accounts (de Roover, 1941), which let them track materials through different production stages and estimate unit production costs. Manufacturers would modify the preceding journal entry to specify that the sale was from Finished Goods inventory.

| | | |
|---|---|---|
| Cash (Debit) | $20 | |
| Revenue (Credit) | | $20 |
| Cost of Goods Sold (Debit) | $15 | |
| Finished Good (Credit) | | $15 |

[7] Money was tracked in physical units under SEB, 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.

We next describe in more detail the history of SEB accounting and DEB's initial use by Italian banks to track loans and its later use by retailers and manufacturers. We discuss later *how* DEB made discovering future profit opportunities easier and *how* this function co-evolved with firms' transactions.

*Accounting Under SEB*

The earliest known accounting artifacts are the baked clay tokens recording transactions from Mesopotamia (now Iraq) circa 8,000 BCE (Schmandt-Besserat 1992a; 1992b).[8] The first tokens were simple shapes (e.g., spheres, cones, and disks) representing physical quantities of cultivated grain and abstract labor units, enabling agricultural cooperation. These records expanded planning horizons since farming takes months compared to the daily food-gathering plans of nomadic hunter-gatherers. Settling down let farmers amass property and livestock, and property claims likely led to a shift from sharing within the kin group to trade between individuals (Sahlins 1972). A system of *bullae* or clay balls encasing tokens emerged (c. 3200 BCE) to record the identities of transacting parties using personal seals (Schmandt-Besserat 1992b), which enabled multi-period contracts where performance tracking mattered. These multi-period contracts sparked the running records that we now call bookkeeping.

Writing first appeared in Egypt around 3,400 BCE and in Mesopotamia near 3,100 BCE and progressed from pictographs to phonograms that were combined in hieroglyphic script (Champollion 1824; Mouck 2004). Like the Mesopotamian tokens, the oldest Egyptian records store data on village-level taxes and arrears using SEB with classified accounts to track commodity totals. Scribes kept detailed inventory lists for the royal storehouses that collected in-kind (usually grain) taxes (Farag 2009).

Grier (1932) describes the SEB records kept by an Egyptian farm manager, Zeno, in the third century BCE, for the owner, Appolonius. The 7,000-acre farm was organized as several functional units

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

with each unit keeping daily records of inflows and outflows (*in physical units* only) for many different commodities like a modern perpetual inventory system. 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, like a petty cash system.[9] Workers were paid in grains (a food allowance) that were tracked separately from money even in the annual accounts.

This extensive system helped monitor the activities of thousands of workers, but it would have been very difficult to assess wealth changes by adding up different physical units (Mickwitz 1937). This is not an isolated example. SEB systems date back thousands of years and were invented and used by many civilizations including Italy before DEB. Thus, large organizations existed and operated profitably using SEB (Yamey 1949; Jack 1966). However, a SEB system lets net assets and periodic profit be determined for an accounting period only if all units are converted into money terms (Childs 1895, 24).

The primary function of Italian SEB was to track debt obligations where the firm was either a borrower or lender, and the books could serve as evidence in legal proceedings (de Roover 1938; Yamey 1949; Martinelli 1974; Sangster 2016). Keeping track of financial obligations would have been of central importance since a reputation for timely repayment of loans is helpful in securing future credit.

*The Early Use of DEB*

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

[9] Jewish charities in Old Cairo c. 1100 AD tracked cash receipts and expenditures in separate columns, and often added up the columns and calculated their difference, but did not advance to DEB (Gil 1976, 54-56).

existence and current balance of a loan made by a banker. The courts came to recognize DEB as the standard for bookkeeping, and this standard was incorporated into Italian law and gained broader acceptance as merchants adopted the method (Sangster 2016, 310-11).

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

Pacioli (1494/1914, chapter 20) explains how DEB is useful because accounts can separate out entries of "the highest importance in commerce" where "without entering the value of the things that you have traded, you could not, from your books and accounts, learn, except with great difficulty, what your profit or loss is." Thompson (1777, book II, chapter I) reinforces this when he notes that accounts categorized by product type are valuable because they provide more precise data on wealth changes:

> "Book-keeping by Double Entry…. is the art of keeping our accompts in such a manner, as will not only exhibit to us our net gain or loss upon the whole, *but our particular gain or loss upon each article we deal in, by which we are instructed what branches to pursue, and which to decline*; a piece of knowledge so very essential to every man in business, that without it a person can only be said to deal at random, or at best can be called but guess'd work." (emphasis added)

Cotrugli (1458/2017, 59-61) advised merchants to be "clever in seeking business, weigh up opportunities and find new ones, for the proof of an active intelligence is finding new things" and to "know the right moment to switch merchandise, when he sees that profits are diminishing because a sector is becoming crowded." Stevin (1607) likewise stressed the importance of profit data by product

type (Yamey 2000, 4-5). Cross-referencing of entries creates linkages within and across transactions that can aid an entrepreneur seeking better access to past data to identify why one type of transaction is more profitable than another type and adapt business decisions accordingly.[10]

The surviving records for Rinieri Fini & Brothers (1296-1305) and Giovanni Farolfi (1299-1300), Florentine firms operating in France, suggest that many key elements of DEB were in place by the late 13th century (Lee 1973, 1977). The surviving "General Ledger" of the Giovanni Farolfi branch in Salon contains debit (credit) accounts in the first (second) half of the book, and includes references to an earlier White Ledger, a Red Book for the main merchandise accounts, a Cloth Ledger for cloth goods, an Expense Book and a Cash Book (Lee, 1977). This inter-related set of books has separate 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. While these inventory accounts did not lead to profit reckoning after each transaction, they did allow more timely profit reckoning as batches of inventory were exhausted (Lane 1945). The surviving ledger reflects an understanding of the algebraic opposition of 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).

Francesco Datini, a 14th century Tuscan merchant, accumulated hundreds of DEB account books and ledgers between 1350 and 1410 (Origo 1957/1986, 107-115). Datini used his accounts directly in his own activities and indirectly through several bookkeepers he employed to monitor foreign branches. His veneration of profit is evident in the invocation "In the name of God and of profit" on the first page of

[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 gross profits for these goods when an inventory had been fully sold or when a venture was dissolved. However, even in these advanced SEB systems competing with rudimentary DEB systems, gross profit was only calculated periodically rather than perpetually.

each new ledger (Origo 1957/1986, 109). Origo (1957/1986, 95) notes that, "Datini made his fortune, not so much by a series of brilliant *coups*, as by an infinitely patient accumulation of small profits – an avoidance of dangers, quite as much as a seizure of opportunities" (original *emphasis*).

Other examples suggest that DEB aids firms in wealth creation. Venetian shippers used venture accounts to track profits in 15th century foreign trading ventures and British merchants later used venture accounting before 1800 (Pacioli 1494/1915, Ch. 20; Winjum 1970; 1972).[11]

*Evolved DEB with income statement accounts*

Prior research suggests that three conditions must be met for a company to be defined as using full-fledged DEB (Zerbi, 1952, as listed in de Roover, 1955). First, each transaction is recorded twice with dual effects captured by equal debits and credits (Martinelli 1974, 217). Second, a DEB firm's chart of accounts includes a "set of accounts opened to expenses and revenues, the so-called 'income accounts'" in addition to the permanent accounts for assets and liabilities already present under SEB (Martinelli 1974, 220). Finally, the debit and credit side of the entry are linked by cross-reference or recorded so that the location of the other side of the entry is obvious by how it is recorded (Martinelli 1974, 271).[12]

As DEB came to include separate revenue and expense accounts that labeled the sources of wealth changes due to transactions, the splitting of the trial balance into a balance sheet and an income statement became more common in the mid-1500s. Many surviving account books of the Medici and other Florentine families provide ample examples of the evolution of double-entry bookkeeping from the 1400s onwards (e.g. de Roover, 1955).

[11] 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.
[12] Although Zerbi (1950) viewed this third criterion as essential, Melis (1950) and de Roover (1955, 411) disagreed, arguing that sometimes books were cleverly structured to make cross-referencing entries redundant.

When wealth-seeking exchanges become frequent, material, heterogeneous and span long periods, DEB facilitates mapping wealth changes to different past transactions. Besides tracking quantities like SEB, DEB encourages 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.

A few factors helped DEB become a predominant business practice. First, entrepreneurs learned how to use DEB better. Widespread Italian *abaco* schools and textbooks increased access to DEB knowledge. Second, entrepreneurs exploited DEB analysis to conceive and act upon new exchange opportunities – e.g., future transactions that entail more complex marketing, production, or delivery operations. Third, effective use of DEB requires a conducive business environment, which includes the broad acceptance of virtuous and prudent profit seeking by entrepreneurs (McCloskey 2016). If these conditions are met, along with the availability of money, algebra, writing, and other needed institutions (Littleton 1927), then DEB could become used more widely as firms expanded in scale and scope.

*Advanced DEB with manufacturing cost accounts*

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

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

> "(T)he whole development of accounting has been a very gradual process – *natura non facit saltum* – and cost accounting has been no exception. One cost accountant or bookkeeper passed on his

> methods to another for experiment and trial rather than writing textbooks or learned articles…. (I)t should be noted that perhaps another reason why so little was written on cost accounting before 1855 was the traditional attitude of business men towards divulging any comparative advantages in manufacturing techniques to possible competitors. The handling of a firm's accounts in an especially advantageous way was considered personal, a secret not to be let out to rival firms."[13]

U.S. meatpackers made extensive use of cost estimates in running their businesses. Bliss (1922, 290) notes that these costing systems were based on "up-to-the-minute and reliable information as to costs" as well as "the most recent information as to the markets and costs of live animals." The costing systems of meatpackers (as in other industries) were built on a foundation derived from DEB's usefulness in storing classified cost data useful for marketing, production, and investment decisions (Garcke and Fells 1889, 4-11; Hawkins 1905, 1-10; Gilman 1911, 249).

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

Future business decisions can be affected by the original cost classification scheme. Littleton (1953, 122) remarks that because of "standard cost methods fitted into the double-entry type of

[13] Garner (1954/1976, 25) notes that the rudimentary cost accounting techniques used by the Italians "gave impetus to the early growth of double entry bookkeeping by showing its adaptability to new and different situations" that underlay the "relationship between the growth of bookkeeping and capitalism" (Garner 1954/1976, 17).

account-categories, we have in the result a convincing demonstration of the amazing adaptability of the scheme of classifying data that took form in its essential features, five centuries ago." In evolutionary terms, DEB adapted to mass manufacturing environments to add value by better identifying unit costs to match against sales and later to control costs by reducing inefficiency (Fleischman and Tyson, 1998).

## III. *WHY* ENTREPRENEURS INCREASINGLY CHOSE DEB OVER SEB

We hypothesize that entrepreneurs chose DEB because measuring profit for individual sales transactions helped them learn about (i.e., "discover") opportunities for profitable future exchanges. The definition of wealth as a residual claim capturing the difference between assets and debts, later supplemented with income accounts, likely changed how entrepreneurs viewed their business activities. Russell and Whitehead (1910, 11-12) argue that definitions are crucial because they (a) point to something important worth understanding, and (b) often analyze a common idea from a different perspective, making definite what had previously been vague and thus sharpening knowledge.

Once ownership wealth was defined clearly and measured more precisely with DEB, merchants could focus on increasing this wealth metric. Since most Italian businesses were family enterprises, this new definition of equity likely spurred a separation of previously commingled personal and business accounts.[14] The concepts of profit and wealth existed under SEB; DEB likely enabled continuous profit tracking and measurement of profit by product type.

We hypothesize that DEB use by firms changed (1) entrepreneurial thinking about economic exchange, (2) the accounting practices used to estimate transaction-specific profits, and (3) firm scale and scope. We discuss the first issue in this section and then describe how DEB altered transaction analysis and the scale and scope of firms' operations, respectively, in the next two sections.

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

*DEBITS=CREDITS and the Demand for Conceptual Accounting Knowledge*

Economic exchange occurs when a buyer and seller both expect to be better off after a contemplated transaction. When a buyer pays $20 for a baseball bat, he expects to be at least as well off than he would by keeping the $20 and not buying the bat. Hence, his increase in bats and reduction in cash are causally linked. DEB reflects this causation by simultaneously recording the increase in bats with the decrease in cash as equal valued debits and credits in a journal entry.

Ijiri (1975, 84) explains how DEBITS=CREDITS leads a DEB accountant to see a transaction very 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 a simultaneous offsetting change.[15] Algebra is much harder than arithmetic, which likely explains why so many first-time accounting students find DEB difficult and unintuitive.

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

Schelling (1995) suggests that the DEBITS=CREDITS equation is not obvious *ex ante* but with careful definition seems obvious *ex post* (see also Jensen 1983). 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 due. Regardless of its cause, the immediate effect of DEB was a more careful definition of the residual difference between asset values, and this seemingly minor shift transformed transaction analysis.

Ijiri (1967, 102-105) uses "causal double-entry" to label how DEB helps a merchant understand profit sources better than SEB.[16] Ijiri (1993, 273) elaborates:

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

We analogize DEB to a set of eyeglasses that sharpen eyesight relative to SEB – see Figure 2.[17] Absent eyeglasses, an entrepreneur's perception of profit from individual past transactions is blurry

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

[17] Jan Christoffels Ympyn (1547 Chapter 2) uses a similar metaphor in his DEB textbook when advising the merchant, "At least once in the year, to peruse and cast over his book to see what state and condition that he stands in, and not to proceed confusedly, not knowing whether he increase or go backward, whereby many

even though he accurately sees total profit when his assets and debts are valued (Panel A). As a result, his memory of profit from individual past transactions is fuzzy. Panel B shows how eyeglasses sharpen the entrepreneur's focus by letting him see specific past transactions more clearly. Better vision lets him recall the past more accurately and better predict future profits by product and in total. DEB likely 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 focus on more profitable products that improve total profits. Second, DEB's timely and accurate profit data lets a merchant experiment with product changes and marketing activities and more accurately determine if these trials succeeded.

Transaction analysis is complex under DEB because implementing DEBITS=CREDITS raises valuation issues.[18] 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, which of the three values should be adjusted to make the debits and credits balance, and why?

Nominal (income statement) accounts introduce new questions about profit measurement and future contingencies. What is the value of inventory made by the seller? Is there hard evidence that a sale is at arm's length? What should be the carrying value of a damaged asset? Can sales revenue be recognized when the seller has performed some, but not all, of the contracted tasks? How should the costs borne in anticipation of a future sales transaction be recorded? Accountants still grapple with these questions that underlie the *Historical Cost*, *Objectivity*, *Conservatism*, *Revenue Recognition*, and

---

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).

[18] Ijiri (1981, 21) shows how the historical cost principle is a natural result from the DEBITS=CREDITS constraint using an example of an inventory purchase drawn from Pacioli (1494/1914, chapter 18).

*Matching* principles that emerged from accounting practice over several centuries (Littleton 1933; Gilman 1939; Paton and Littleton 1940; Chatfield 1974). These questions all tie back to profit calculation at the exchange, product, and/or the firm level, but first arise when recording a journal entry under DEB.

DEB is advantageous in part because merchants mentally evaluate sales differently. After a sale, SEB bookkeepers separately record how physical resources changed, i.e., cash rose and inventory fell. With DEB, one accountant must track both items, and will more likely consider future contingencies before recording a journal entry. For example, can and will the customer return the product? For a credit sale, is the customer likely to pay on time? If the firm has a future performance obligation, what are its likely future costs? Thus, DEB requires the accountant to mentally simulate future scenarios to assess risks and uncertainties (Suddendorf and Corballis 2007; Seligman, Railton, Baumeister, and Sripada 2017), leading to a prospective focus that can improve discovery of future profit opportunities.

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

Accounting principles were induced from practice through legal cases and accounting theory textbooks (Chatfield 1974; Baskin and Miranti 1997; Previts and Merino 1998). Auditing firms that 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 bottom-up ecological rather than top-down constructivist rationality (Smith 2003; Waymire and Basu 2007, 94-104; Basu 2015).

Three points about evolved accounting principles are important for present purposes. First, modern accounting principles, especially those for revenues and expenses, essentially assume that financial statement preparers use DEB. We infer this because SEB does not typically involve income measurement – 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, accounting and transactions co-evolve. If all transactions were settled immediately in cash, then the accounting rulebook would be a brief pamphlet. Third, the division of financial reporting and management accounting is an artifact of modern research, complex organizations, and extensive accounting regulation. Most accounting principles have their historical roots in eras that differed in many ways from today's institutional structures.

Early textbooks and curricula in *abaco* schools emerged to store and diffuse the growing conceptual accounting knowledge.[19] 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 lets future generations deal with even more complex transactions; accounting practice could co-evolve with economic exchange in "ratchets" up to higher knowledge scaffolds (Tomasello 1999, 37).[20] Institutions like DEB likely change in function (i.e., undergo exaptation) as transactions and economic environments grow more complex.

[19] 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).

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

*DEB Strengthens Feedback in Mental Models of Exchange*

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

We hypothesize that managers perceive future profit opportunities differently under DEB and SEB. People use mental models, which are symbolic representations that imperfectly capture some crucial aspects of real-life events and interactions (Johnson-Laird 1983). Thus, a mental model of the solar system is many marbles revolving around a basketball. Craik (1943, 61) notes that a decision-maker's mental model helps him "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 build and then iteratively refine mental models by analogizing from their experience in a *base* domain to a *target* domain where they are novices (Collins and Gentner 1987, 245-8). People simulate what they already do in new imaginary situations, and this learning from experience induces cognitive change (Johnson-Laird 2013, 132-5). The mental model helps distinguish "signal" from "noise" when prediction is necessary (Filipowicz, Anderson, and Danckert 2016).

The mental models constructed under DEB are more tightly linked through causal exchange interactions than those under SEB. DEB leads more directly to consideration of costs in connection with revenue generation since the DEBITS=CREDITS rule leads to recording costs associated with transactions (Ijiri 1981, 21). Specifically, historical cost emerges naturally with DEB where resource movements are

recognized more quickly than with SEB, and this advantage is increased when a firm transacts more often and can more accurately predict future outcomes (Ijiri 1981, 26-32).

Thus, mental models of economic exchange will differ under DEB and SEB. Consider a $20 cash sale of a baseball bat that had cost the seller $15. This sale has two easily observed effects: a decrease of one bat and a $20 cash increase. A bookkeeper using SEB will record *only* these effects, but an accountant using DEB will need to measure the value of the transaction using known facts (e.g. who, what, where, when, why, how, and prices). Most importantly, precisely measuring the gain or loss *after* each sale helps the manager understand why it occurred and can help identify profitable prospects *before* purchasing or making new inventory.

Finely classified DEB-based historical data are likely useful in this regard. Ijiri (1981, 33) states that historical cost data derived from DEB transaction records "provides a basis for developing criteria for choosing the best model among many since we prefer to rely on a model that worked well in the past, and whether a model has worked well or not must be determined on the basis of past records." The flexibility of DEB account categories lets accountants track and simulate different product costs and provide a vital input for future product decisions (Littleton 1953, 54-5).

Figure 3 depicts differences in a 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 considering 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 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, an entrepreneur will identify this sooner and more accurately with DEB and can expand production or develop new related products sooner than with

SEB.[21] A lower profit signals less product demand, which may require product improvements, or in extreme cases, a change in product offerings. If feasible product improvements will not restore demand, then the entrepreneur might rightly decide to exit from the product market.

*DEB and Exchange Evaluation by the Human Brain*

Frequent use of DEB can alter neural connections within the brain. Hayek (1952, 123-4) suggests that mental models are represented in the connections between neurons and their patterns of interaction, and that these connections are crucial to memory formation and learning. Hebb (1949) and Hayek (1952) independently hypothesized that a person's experience shapes brain structures – i.e., the human brain is "plastic." Brain changes have been measured for musicians learning a new instrument and London cab drivers memorizing its map (Maguire et al. 2000; Munte et al. 2002; Nutley et al. 2014; Schlaug 2001). We expect that DEB has similar effects on accountants, e.g., enlarged brain regions with stronger connections in processing rewards, sacrifices/pain, quantification, and social cognition.

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 improved experiential learning (Rosenzweig, Bennett, and Diamond 1972; Quartz and Sejnowski 1997; Doidge 2007).[22]

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

[21] 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 result from the "adjacent possible" (Johnson 2010).

[22] 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.

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). 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).[23]

We suggest 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.

We expect that a mental model shaped by DEB will lead an accountant-entrepreneur to better understand how operational changes might affect future profits. For example, a DEB-based mental model would let a durable goods producer forecast more accurately how sales and costs would change if it offers a new product warranty. A DEB-based mental model focused on future profit will also better comprehend the "value chain" that makes a product desirable. This mental model will help decide whether to change a product element or to expand into markets for complementary products. DEB-based data from past transactions can help an entrepreneur conduct a "what if" analysis for future transactions based on their similarity to prior experience (Ijiri 1981, 29).

## IV. *WHY* GLOBAL ECONOMIES SELECTED DEB FIRMS OVER SEB FIRMS

[23] 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."

DEB evolution was not consciously directed by any individual or group to shape a specific historical outcome. Wilson (2019, 18) notes that natural selection occurs by testing new alternatives' *survival properties* in a specific environment. He summarizes how a biological trait evolves as, "mutation proposes, the environment disposes". Cultural innovations face the same selection forces as biological traits (Campbell 1960; Dawkins 1976; Richerson and Boyd 2005). In both types of evolution, the forces guiding selection can change over time; exaptation often results in a new primary functional emphasis (Gould and Vrba 1982; Johnson 2010, 151-75). We argue that DEB ultimately enabled more timely and accurate discovery of future profit opportunities because of a profit-measurement exaptation.[24]

Werner Sombart's emphasis on the profit motive and the significance of DEB suggests an important question: does the accountant's profit calculation under DEB lead to more effective discovery of future profit opportunities and greater wealth generation than SEB? We now consider this question.

*DEB and the Scale and Scope of Business Organizations*

An entrepreneur adjusts the scale and scope of his firm in pursuing higher profits. Adam 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." That is, a filet mignon reaches our table because a butcher carries an inventory of prime steaks in anticipation of earning a profit. But how would a butcher know what products to carry and what prices to charge?

This process begins when a local butcher asks: "Will a customer pay enough for high quality steaks to yield me a profit?" All else equal, we expect that he 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

[24] Skeptics and proponents of Sombart's Hypothesis likely differ in their focus on ultimate vs. proximate causation. Yamey (1949; 1964) asked skeptically that if managers used DEB primarily to measure profits, why did it take until the 19th century before firms routinely produced firm-wide income statements? We argue that the proximate forces for DEB's emergence likely differed from those that drove its long-run success over centuries (Garner 1954/1976, 29-30), as indicated by the varying historical uses of DEB summarized in previous sections.

sold more of those cuts recently. That is, he could "simulate" his customers' demand more accurately because he can access both price and quantity data on sales with DEB but only the latter with SEB. However, Smith's artisanal butcher would benefit little from DEB. A high-volume meat supplier would benefit more from DEB since it provides more useful feedback than SEB as transaction volume rises.[25]

In 1800, the U.S. meatpacking industry was comprised mainly of retail butchers who bought local farm animals and sold dressed meat in local shops. Meatpacking, like many industries, was transformed in the 19th century when wholesalers expanded nationally aided by the extensive U.S. railroad network and the invention of refrigerated boxcars (Chandler 1977, 299-301; Grand 1903; Hill 1923). Large beef wholesalers like Swift and Armour developed sophisticated product "cost finding" systems (Kimball 1917; Chandler 1977). Unlike manufacturers that combine inputs to produce something, the cost accounting for a meatpacker was complex because a joint input (livestock) is divided into dressed beef and by-products like hides and fat (Putnam 1921; Bliss 1922).[26]

The benefit to a 19th century meatpacker of using DEB would be limited by scale of operation – i.e., a meatpacker could earn sizable profits only if small profits from each transaction were scaled up to thousands of transactions. This effect, however, could be huge if we consider the cumulative effect across all firms worldwide. The result is that DEB may have a large aggregate effect and still not be well understood by decision makers or the scholars who study such behavior. More to the point, we have

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

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

trouble grasping the significance of DEB because we cannot observe the counterfactual performance of a firm or a macroeconomy where only SEB is available – i.e., nobody knows DEB's opportunity cost.[27]

*DEB, Entrepreneurial Alertness, and the Strategic Flexibility of Large Organizations*

A DEB-based mental model will help an "alert" entrepreneur better discover future profits (Kirzner 1973, 223; Hayek 1968, 181-2). Entrepreneurs react to price changes and increased orders because they inform them of changed profit opportunities. In Hayek's words, entrepreneurs "direct their attention" to discovering whether local price changes can improve their profits given the cost of meeting the demand for the product. An entrepreneur considers easily available data when evaluating environmental changes. We contend that these evaluations will be more accurate, and the responses will be more effective when the entrepreneur is guided by the more precise and timely data provided by DEB (Waymire 2009). DEB-based cost systems would provide richer context-dependent data that would encourage serendipitous discovery of new opportunities in neighboring product spaces (Johnson 2010, chapter IV). As a result, DEB-based economies will have fewer unexploited Pareto-improving trades that Schelling (1995, 22) describes as "free lunches all over waiting to be discovered or created."

A firm's historical results stored in a DEB system fosters tighter causal connections in a decision maker's mental model between past outcomes and the decisions to initiate future transactions. These connections entail simulated mental time travel that links the firm's current transactions to past consummated exchanges as well as to future contemplated transactions. This mental time travel is useful because it integrates control (an activity focused on the recent past) and planning (a more future-oriented activity) (Ijiri 1981, 29). Planning by firms is improved by DEB use (Most 1973) since DEB applied to large numbers of "localized" transactions results in a "complex whole" created by the

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

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

A single merchant using DEB (unlike his competitors) within a competitive discovery process (Hayek 1968, 181) can sell products at lower margins than his competitors. Competitors using SEB will likely lose by a small amount on average if they try to compete head on, but they can survive if they locate market niches. Similarly, a firm insulated from market competition by government-granted monopoly – e.g. the Dutch East India Company cited by Yamey (1964, 126-130) – would more likely survive using SEB. Like any management tool, more effective use of DEB will generate higher volume and profit and lead to positive skewness in the distribution of profits and firm size (Ijiri and Simon 1967; Demsetz 1973). Industries that invested early in modern information systems have more positively skewed profitability and firm size, consistent with our hypothesized advantage in assessing product-specific profit contributions (Bessen 2017).

Nineteenth century steel magnate Andrew Carnegie is an exemplar. He took a night school course as a young man to learn DEB because "all the great firms kept their books in double entry" (Carnegie 1920, 36). The partnership agreement at Carnegie Steel required that DEB be used for accounting (Bridge 1903, 5-8), and Carnegie used a DEB-based cost accounting system to successfully implement a "cost leadership" strategy that let him undercut his competition on large jobs (Johnson and Kaplan 1987, 32-34). Carnegie's success was partly due to his having more accurate cost data than his SEB competitors who computed profits only once per year (Carnegie 1920, 135).[28]

[28] The kinds of weaknesses in cost accounting addressed by Carnegie were not unique to steelmaking. In remarking on durable goods industries generally, Garner (1954/1976, 29) says that "it was the custom to estimate costs and tender bids to prospective buyers. What was more logical than to take the next step; that is, after accepting a contract for a certain project, to keep some sort of collective details as to the costs of executing the contract in order to ascertain the profit or loss thereon, and to provide information for future estimates? Obviously, this is known today as job order costing, and some of the modern cost accountants' most difficult problems grew out of those humble beginnings."

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

Since SEB firms could survive in turbulent environments (Yamey 2000) and transactional complexity was limited for a long time, DEB diffused slowly. This likely explains, at least in part, why the effect of DEB on entrepreneurial behavior and mental attitudes diffused very gradually. Nonetheless, we hypothesize that over the long-run (1) firms that adopted DEB earlier earned higher average profits, and (2) the spread of DEB beyond Renaissance Italy led to increased wealth in regions where entrepreneurs more frequently used DEB. This is, as already noted, consistent with a long-run co-evolution of DEB with mental models of exchange and increasing complexity and scale of profitable economic exchange.[29]

## V. FUTURE RESEARCH ON DEB EVOLUTION

We now offer suggestions for empirical research on DEB's function, mechanism, and adaptive significance. We emphasize that DEB emerged spontaneously as individuals responded to proximate causes to adopt DEB and modified it to their own uses at that time. Over the long haul, these actors did

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

not (and could not) comprehend how DEB would later be adapted to new uses reflecting deeper ultimate causes. This suggests that traditional approaches looking for statistical regularities in a regression model where a change in X leads to an immediate change in Y will be incomplete. We thus emphasize approaches that will help us better understand the counterfactual case of how the world would differ if DEB never been invented. This requires us to consider whether and how modern society could have been possible in a counterfactual world where only SEB were available.

*Research on WHAT changes firms make when switching to DEB from SEB*

As a first step, we encourage research on how a firm initially decides to adopt DEB. Most firms likely start out using SEB and only later adopt DEB. When does this occur – is it after the company has experienced "growing pains" as they try to scale in size? Does DEB adoption occur when a firm first gets information indicating a near-term sales volume increase? How costly is it to adapt a SEB system to one based on DEB? This topic would be well-suited to the use of survey methods. The sample for such a study could include entrepreneurs who have adopted DEB and the consultants that advise clients on the design and implementation of DEB systems. Examples of a similar approach are Allee and Yohn (2009) and Cassar (2009).

This research could be extended to study both the demand and supply sides of the market for bookkeeping services.[30] What kinds of firms seek bookkeeping services – are they profitable entities or are they losing money and need assistance in organizing their operations? What determines whether a firm does its own bookkeeping or outsources it to an external supplier? If done in-house, what specific backgrounds are sought in persons hired as bookkeepers? What professional training is needed to do this – e.g., at what point does a company hire a CPA to oversee its accounting function? If the

[30] A reasonable starting point for such a study would be to pose a question to the Google search engine like "How do I implement a double-entry bookkeeping system in my company?"

bookkeeping function is initially outsourced, how long does this last and what conditions lead to internalizing the accounting function?

Research on DEB's function should also explore profit estimation and track changes within firms after they adopt DEB. Does DEB adoption lead to changes in the specificity of revenue and expense accounts that a firm uses? If so, is there a materially finer disaggregation of transactional data by firms after they switch from SEB to DEB? How soon does this occur? Do firms switching to DEB have a "big bang" expansion in their chart of accounts, or does this emerge incrementally? Finally, do any firms retrofit their SEB accounting system to track profits by product type? If so, how well does this work?

*Research on HOW the use of DEB evolves with individual experience*

Researchers should investigate how DEB changes transaction analysis. Process-tracing techniques can be used to decompose the steps used by accountants in transaction analysis and how that process changes for firms adopting DEB (Ford et al. 1989). A starting point would be to understand how someone analyzes a profit-seeking transaction if they have never been exposed to DEB. The sample for a such a study might be college freshman before any exposure to DEB.

Using a sample of students learning DEB for the first time, how do new accounting students learn to do basic transaction analysis before recording a journal entry for sales revenue? Does this vary as future collection becomes more uncertain? Do they start from previous cases or do they begin 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 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)? The use of a brain mapping

experiment (e.g., fMRI technology) might be useful in identifying differences in DEB- vs. SEB-based transaction analysis.

A broader research question is how DEB shapes a businessman's mental perspective of profit generated by the firm's interactions with consumers. We predict that experience working with DEB-based profit data will help an entrepreneur better identify conditions where a small positive profit is more likely than a small loss and more accurately forecast overall profits and its components. Does higher quality DEB data on profits lead to better strategic decisions in response to environmental changes? A two-part laboratory experiment could be used to investigate these questions. A first task could have both accountants and non-accountants analyze a series of transactions and forecast future profits. A second task would be to have subjects 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 both 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 physiological changes in student brains during their first accounting 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 are affected by learning DEB.[31] 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 used in accounting tasks when they start the course?

[31] Dickhaut, Basu, McCabe, and Waymire (2010) and Birnberg and Ganguly (2012) discuss the prospects for neuroscientific accounting research more generally.

*Research on WHY DEB Firms Perform Better*

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

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

Obtaining data to test these predictions is difficult but not impossible. Comparative historical case research on early DEB adopters can be conducted using 13$^{th}$ and 14$^{th}$ 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.

The second part of this research question is whether and how soon DEB introduction leads to greater realized gains in a firm and its economy. We suggest two ways to explore this critical issue. One is to examine changes in competitive dynamics within an industry when one or more firms gains access to DEB-based 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. One 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 simulation would provide evidence on DEB's survival value compared to SEB.

A final opportunity is to study whether the geographical diffusion of DEB beyond Italy was historically associated with improved macro-economic performance. For example, one could track when Pacioli's original text was translated into different local languages or when the arrival of DEB was documented by ethnographers studying a country or region.[32] One can then test for macroeconomic performance improvements following DEB introduction dates, although we have to remember that DEB diffused unevenly within an economy – e.g., early uses of DEB (recording transactions) were more rudimentary than later ones (financial statement preparation).

## VI. CONCLUDING REMARKS

We theorized about why single-entry bookkeeping (SEB) was gradually displaced by double-entry bookkeeping (DEB) over the course of eight centuries. We focused on three issues. First, we hypothesized that *what* DEB did better was improve discovery of future profit opportunities. Second, we

[32] 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-related variables is the Human Relations Area Files (HRAF). The HRAF includes a variable measuring the presence of DEB in a society.

argued that *how* DEB evolved was by exploiting the DEBITS=CREDITS constraint, which led to crisp definitions of revenue and expense by revealing a demand for knowledge about how to increase wealth. Third, we hypothesized that *why* surviving firms increasingly use DEB is that it helps expansion in scale and scope by exploitation of cost-leadership strategies.

Like Ijiri (2005), our perspective on DEB is dualistic. First, DEB measures profit contribution from *past* transactions, but its main consequence is better discovery of *future* profit opportunities. Second, the collective benefits of DEB could be huge but go unnoticed because the benefits accrue in small increments over many transactions. DEB could have a big unrecognized economic impact akin to a "vein of water flowing hidden underground, secretly making the ground green" (Carlyle 1888, volume VI, 107).

Our analysis suggests at least two hard-to-observe 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 profit measurement and valuation. Second, consistent DEB use affects a company's profit through a long-term co-evolution of accounting practice, the depth of analysis of economic exchange, and the resultant profitability from economic exchange.

Parsing out the unique effect of DEB on the wealth of firms and societies will be difficult – i.e., "endogeneity" will be omnipresent in naturally occurring data. Designing laboratory experiments that address endogeneity will be difficult, and may only demonstrate how the data that *could* be produced under SEB yields different economic outcomes than the type of data that was likely provided by DEB.

The question underlying our paper, which may be unanswerable, is: how did DEB alter the world? More precisely, the big question about DEB is: if accounting knowledge had been frozen at levels present before DEB was invented (ca 1,200 AD), would the world we live in be the same as the one we live in today? Basil Yamey proposes that not much would be different had accountants used SEB for the past 800 years. A.C. Littleton, Yuji Ijiri, and we propose instead that DEB had a profound effect on the

quality of human existence. Determining how well these views depict DEB's importance is an important endeavor for future accounting research.

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

Over the long-run, this research will let us coherently answer future students who ask why we only teach them DEB-based accounting. Hatfield (1924, 253) suggested a partial answer about DEB:

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

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

**REFERENCES**


Allee, K. and T. Yohn, 2009. The demand for financial statements in an unregulated environment: an examination of the production and use of financial statements by privately-held small businesses. *The Accounting Review* 84 (1): 1-26.

Ball, R. 2001. Infrastructure requirements for an economically efficient system of public financial reporting and disclosure. *Brookings-Wharton Papers on Financial Services* 127-69.

Barton, J., G. Berns, and A. Brooks, 2014. The neuroscience behind the stock market's reaction to corporate earnings news. *The Accounting Review* 89 (6): 1945-1977.

Baskin. J. and P. Miranti, 1997. *A History of Corporate Finance*. Cambridge, UK: Cambridge University Press.

Basu, S., 1997. The conservatism principle and the asymmetric timeliness of earnings. *Journal of Accounting and Economics* 24 (1): 3-37.

Basu, S., 2015. Is there any scientific basis for accounting? Implications for practice, research, and education. *Journal of International Accounting Research* 14 (2): 235-265.

Basu, S., and G. Waymire, 2006. Recordkeeping and human evolution, *Accounting Horizons* 20 (3): 201-229.

Basu, S., and G. Waymire, 2018. Historical cost and conservatism are joint adaptations that help identify opportunity cost, *Accounting, Economics and Law: A Convivium*, forthcoming.

Basu, S., J. W. Dickhaut, G. Hecht, K. Towry, and G. B. Waymire, 2009. Recordkeeping alters economic history by promoting reciprocity. *Proceedings of the National Academy of Sciences of the U.S.A.* 106 (4): 1009-1014.

Basu, S., M. Kirk, and G. B. Waymire, 2009, Memory, transaction records and *The Wealth of Nations*, *Accounting, Organizations and Society* 34 (8): 895-917.

Benson, B., 1989. The spontaneous evolution of Common Law. *Southern Economic Journal*, 55 (3): 644-661.

Berman, H., 1983. *Law and Revolution: The Formation of the Western Legal Tradition*. Cambridge, MA: Harvard University Press.

Bessen, J., 2017. Information technology and industry concentration. Unpublished working paper, September 2017.

Birnberg, J., and A. Ganguly, 2012. Is neuroaccounting waiting in the wings? An essay. *Accounting, Organizations and Society* 37 (1): 1-13.

Bliss, J. H., 1922. Costs and accounting methods in the packing industry. *Administration: The Journal of Business and Control* 3: 279-290.

Bliss, J. H., 1924. *Management Through Accounts*. New York, NY: Ronald Press.

Boyd, R., P. J. Richerson, and J. Henrich, 2011. The cultural niche: Why social learning is essential for human adaptation. *Proceedings of the National Academy of Sciences of the U.S.A.* 108 (Supplement 2): 10918-10925.

Breiter, H., I. Aharon, D. Kahneman, A. Dale, and P. Shizgal, 2001. Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron* 30: 619-639.

Bridge, J., 1903. *The Inside History of the Carnegie Steel Company*. New York, NY: Aldine Book Co.

Brown, M., and Z.-V. Palmrose, 2005. *Thog's Guide to Quantum Economics: 50,000 Years of Accounting Basics for the Future*. Thogian Press, Duvall, WA.

Buonomano, D. and M. Merzenich, 1998. Cortical plasticity: from synapses to maps. *Annual Review of Neuroscience* 21: 149-186.

Bushman, R., A. Lerman, and F. Zhang, 2016. The changing landscape of accrual accounting. *Journal of Accounting Research* 54 (1): 41-78.

Byrne, G., 1937. To what extent can the practice of accounting be reduced to rules and standards? *Journal of Accountancy* 64 (5): 364-379.

Campbell, D. T., 1960. Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review* 67 (6): 380-400.

Carlyle, T., 1888. Varnhagen Von Ense's memoirs, in Volume VI of *Critical & Miscellaneous Essays: Collected and Republished*. London: Chapman & Hill.

Carnegie, A., 1920. *The Autobiography of Andrew Carnegie*. Boston & New York: Houghton Mifflin Co.

Carruthers, B. G., and W. N. Espeland, 1991. Accounting for rationality: double-entry bookkeeping and the rhetoric of economic rationality. *The American Journal of Sociology* 97 (1), 31-69.

Cassar, G. 2009. Financial statement and projection preparation in start-up ventures, *The Accounting Review* 84 (1): 27-51.

Champollion, J.-F., 1824, *Précis du système hiéroglyphique des anciens Égyptiens*, Royal Printing, France.

Chandler, A., 1977. *The Visible Hand*. Cambridge, MA: Belknap Press.

Chatfield, M., 1974. *A History of Accounting Thought*, Hinsdale, IL: Dryden Press.

Childs, C.W., 1895. *The New Essentials of Book-keeping for Public Schools: Single and Double Entry*. San Francisco: Whitaker & Ray Co.

Collins, A. and D. Gentner, 1987. How people construct mental models. In D. Holland and N. Quinn (eds.) *Cultural Models in Language and Thought*. Cambridge, UK: Cambridge University Press.

Cotrugli, B., 1573/1917. *The Book of the Art of Trade*. Palgrave Macmillan: Cham, Switzerland.

Craik, K., 1943. *The Nature of Explanation*. Cambridge, UK: Cambridge University Press.

Demski, J. S., 2007. Is accounting an academic discipline? *Accounting Horizons* 21 (2): 153-157.

Demsetz, H., 1973. Industry structure, market rivalry, and public policy. *Journal of Law and Economics* 16 (1): 1-9.

de Roover, R., 1938. Characteristics of bookkeeping before Pacioli. *The Accounting Review* 13 (2): 144–9.

de Roover, R., 1941. A Florentine firm of cloth manufacturers. *Speculum* 16 (1): 3–33.

de Roover, R., 1955. New perspectives on the history of accounting. *The Accounting Review* 30 (3): 405–420.

Dichev, I. and V. Tang, 2008. Matching and the changing properties of accounting earnings over the last 40 years. *The Accounting Review* 83 (6): 1425-1460.

Dickhaut, J. W., S. Basu, K. A. McCabe, and G. B. Waymire, 2010. NeuroAccounting: Consilience between the biologically evolved human brain and culturally evolved accounting principles. *Accounting Horizons* 24 (2), 221-255.

Doidge, N., 2007. *The Brain that Changes Itself*. London, UK: Penguin Books.

Eisenstein, E., 1979. *The Printing Press as an Agent of Change*. Cambridge UK: Cambridge University Press.

Ellerman, D., 2014. On double-entry bookkeeping: the mathematical treatment, *Accounting Education: An International Journal* 23(5), 483–501.

Eskenazi, P., F. Hartmann, and W. Rietdijk, 2016. Why controllers compromise on their fiduciary duties: EEG evidence on the role of the human mirror neuron system. *Accounting, Organizations and Society* 50 (1): 41-50.

Farag, S. M., 2009, The accounting profession in Egypt: Its origin and development, *International Journal of Accounting* 44 (4): 403-414.

Farrell, A., J. Goh, and B. White, 2014. The effect of performance-based incentive contracts on System 1 and System 2 processing in affective decision contexts: fMRI and behavioral evidence. *The Accounting Review* 89 (6): 1979-2010.

FASB, 1984. Statement of Financial Accounting Concepts Statement 5, *Recognition and Measurement in Financial Statements of Business Enterprises*. Norwalk, CT: Financial Accounting Standards Board.

Filipowicz, A., B. Anderson, and J. Danckert, 2016. Adapting to change: The role of the right hemisphere in mental model building and updating. *Canadian Journal of Experimental Psychology* 70 (3): 201-218.

Fleischman, R. K., and T. N. Tyson, 1998. The evolution of standard costing in the U.K. and U.S.: From decision making to control. *Abacus* 34 (1): 92-119.

Ford, J. K., N. Schmitt, S. Schechtman, B. Hults, and M. Doherty, 1989. Process tracing methods: contributions, problems, and neglected research questions. *Organizational Behavior and Human Decision Processes* 43: 75-119.

Garcke, E. and J. M. Fells, 1889. *Factory Accounts: Their Principles and Practice*. London, UK: Crosby, Lockwood and Son.

Garner, S. P., 1954/1976. *Evolution of Cost Accounting to 1925*. University of Alabama Press (Original issue and later reprint.)

Gil, M., 1976. *Documents of the Jewish Pious Foundations from the Cairo Geniza*. Leiden: E.J. Brill.

Gilman, S.W., 1911. *Auditing and Cost Accounts: Part II*. New York, NY: Alexander Hamilton Institute Press

Gilman, S.C., 1939. *Accounting Concepts of Profit*. New York: Ronald Press.

Gould, S. and E. Vrba, 1982.Exaptation – a missing term in the science of form. *Paleobiology* 8 (1): 4-15.

Grand, W. J., 1903. *Illustrated History of the Union Stockyards*. Chicago, IL: Thomas Knapp.

Greer, H., 1936. Accounting for by-products and joint products. *NACA Bulletin* August 15: 17-24.

Grier, E., 1932. Accounting in the Zenon Papyri. *Classical Philology* 27(3): 222-231.

Hatfield, H. R., 1909. *Modern Accounting*. New York, NY: D. Appleton & Co.

Hatfield, H. R., 1924. An historical defense of bookkeeping. *Journal of Accountancy* 37 (4): 241-253.

Hayek, F., 1945. The use of knowledge in society. *The American Economic Review* 35(4): 519–530.

Hayek, F., 1952. *The Sensory Order*. Chicago, IL: University of Chicago Press.

Hayek, F., 1967. The result of human action but not of design. In *Studies in Philosophy, Politics, and Economics*, 96-105. Chicago, IL: University of Chicago Press.

Hayek, F., 1968. Competition as a discovery procedure. In *New Studies in Philosophy, Politics, Economics, and the History of Ideas*, 179-190. Chicago, IL: University of Chicago Press.

Hawkins, L. W., 1905. *Cost Accounts: An Explanation of Principles*. London, UK: Gee & Co.

Hebb, D., 1949. *The Organization of Behavior*. New York, NY: John Wiley.

Hill, C., S. Suzuki, R. Polania, M. Moisa, J. O'Doherty, and C. Ruff, 2017. A causal account of the brain network computations underlying strategic social behavior. *Nature* Neuroscience 20 (8): 1142-1149.

Hill, H. C., 1923. The development of Chicago as a center of the meat packing industry. *The Mississippi Valley Historical Review* 10 (3): 253-273.

Ijiri, Y., 1967. *Foundations of Accounting Measurement*. Englewood Cliffs, NJ: Prentice-Hall.

Ijiri, Y., 1975. *Theory of Accounting Measurement: Studies in Accounting Research # 10*. American Accounting Association: Sarasota, FL.

Ijiri, Y., 1981. *Historical Cost Accounting and its Rationality*. The Canadian Certified General Accountants' Research Foundation: Vancouver, BC.

Ijiri, Y., 1993. The beauty of double-entry bookkeeping and its impact on the nature of accounting information. *Economic Notes* 22 (2): 265-285.

Ijiri, Y., 2005. U.S. accounting standards and their environment: A dualistic study of their 75-years of transition. *Journal of Accounting & Public Policy* 24: 255-279.

Ijiri, Y., and H. A. Simon, 1967. A model of business firm growth, *Econometrica* 35 (2): 348-355.

Jack, S., 1966. An historical defense of single entry book-keeping. *Abacus* 2 (2): 137-158.

Jensen, M. C., 1983. Organization theory and methodology, *The Accounting Review* 58 (2): 319-339.

Johnson, S., 2010. *Where Good Ideas Come From: The Natural History of Innovation*. New York, NY: Riverhead Books.

Johnson, T. and R. Kaplan, 1987. *Relevance Lost: The Rise and Fall of Management Accounting*. Boston, MA: Harvard Business School Press.

Johnson-Laird, P., 1983. *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. Cambridge, MA: Harvard University Press.

Johnson-Laird, P., 2013. Mental models and cognitive change. *Journal of Cognitive Psychology* 25 (2): 131-138.

Kahneman, D. and A. Tversky, 1979. Prospect theory: an analysis of decision under risk. *Econometrica* 47 (2): 263-292.

Kerr, B. and J. Godfrey-Smith, 2009. Generalization of the Price equation for evolutionary change. *Evolution* 63 (2): 531-536.

Kimball, D. S., 1917. *Cost Finding*. New York, NY: Alexander Hamilton Institute.

Kirzner, I., 1973. *Competition & Entrepreneurship*. Chicago, IL: University of Chicago Press.

Lane, F. C., 1945. Venture accounting in medieval business management. *Bulletin of the Business Historical Society* 19 (5): 164-173.

Lee, G. A., 1973. The Florentine bank ledger fragments of 1211: Some new insights, *Journal of Accounting Research* 11 (1): 47-61.

Lee, G. A., 1977. The coming of age of double entry: the Giovanni Farolfi Ledger of 1299-1300, *Accounting Historians Journal* 4 (2): 79-95.

Littleton, A. C., 1927. The antecedents of double-entry. *The Accounting Review* 2 (2): 140-149.

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

Littleton, A. C., 1937. Concepts of income underlying accounting. *The Accounting Review* 12 (1): 13-22.

Littleton, A. C., 1953. *The Structure of Accounting Theory*. Sarasota, FL: American Accounting Association.

Littleton, A. C. and V. Zimmerman, 1962. *Accounting Theory: Continuity and Change*. London, UK: Prentice-Hall.

Madsen, P., 2011. How standardized is accounting? *The Accounting Review* 86 (5): 1679-1708.

Maguire, E., D. Gadian, I. Johnsrude, C. Good, J. Ashburner, R. Frackowiak, and C. Frith, 2000. Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences of the U.S.A.* 97 (8): 4398-4403.

Martinelli, A., 1974. *The Origination and Evolution of Double Entry Bookkeeping to 1440*. Unpublished PhD Dissertation. University of North Texas.

Martinelli, A., 1977. Notes on the origin of double entry bookkeeping. *Abacus* 13 (1): 3-27.

Mattessich, R. V. A., 2000. *The Beginnings of Accounting and Accounting Thought*. Garland Publishing, New York, NY.

McClelland, J., B. McNaughton, and R. O'Reilly, 1995. Why are there complementary learning systems in the hippocampus and neocortex: Insights from the successes and failures of connectionist models of learning and memory. *Psychological Review* 102 (3): 419-457.

McCloskey, D., 2006. *Bourgeois Virtues: Ethics for an Age of Commerce*. University of Chicago Press: Chicago, IL.

McCloskey, D. N., 2016. *Bourgeois Equality: How Ideas, Not Capital or Institutions, Enriched the World*. University of Chicago Press: Chicago, IL.

Melis, F., 1950. *Storia della Ragioneria*. Cesare Zuffi: Bologna, Italy.

Merton, R. K., 1936. The unanticipated consequences of purposive social action. *American Sociological Review* 1 (6): 894-904.

Mickwitz, G., 1937. Economic rationalism in Graeco-Roman agriculture. *The English History Review* 52(208), 577–589.

Mises, L., 1949. *Human Action: A Treatise on Economics*. Yale University Press: New Haven, CT (Reprinted 1998, Ludwig von Mises Institute, Auburn, AL).

Most, K., 1972. Sombart's propositions revisited. *The Accounting Review* 47(4), 722–734.

Most, K., 1973. The planning hypothesis as a basis for accounting theory. *Abacus* 9 (2): 127-136.

Mouck, T., 2004, Ancient Mesopotamian accounting and human cognitive evolution, *The Accounting Historians Journal* 31 (2), 97-124.

Münte, T. F., E. Altenmüller, and L. Jäncke, 2002, The musician's brain as a model of neuroplasticity, *Nature Reviews Neuroscience* 3 (6): 473-478.

Nussbaum, F., 1933. *A History of the Economic Institutions of Modern Europe: An Introduction to Der Moderne Capitalism of Werner Sombart*. New York: F. X. Crofts.

Nutley, S., F. Darki, and T. Klingberg, 2014. Music practice is associated with development of working memory during childhood and adolescence. *Frontiers in Human Neuroscience* 7: article 926.

Origo, I., 1957/1986. *The Merchant of Prato: Francesco di Marco Datini*. London, UK: Jonathan Cape Ltd.

Pacioli, L., 1494/1914. Summa de Arithmetica Geometria Proportioni et Proportionalita. Reproduced in *Ancient Double-Entry Bookkeeping*, by J. B. Geisbeek, Denver, CO. (by author).

Parr, S., 2016. The epic rise of John D. Rockefeller. *The Hustle*, March 9, 2016. (Available online at https://thehustle.co/the-history-of-john-d-rockefeller-standard-oil).

Parsons, T., 1928. "Capitalism" in recent German literature: Sombart and Weber. *Journal of Political Economy* 36 (6): 31-51.

Parsons, T., 1929. "Capitalism" in recent German literature: Sombart and Weber (Concluded). *Journal of Political Economy* 37 (1): 31-51.

Paton, W. and A. C. Littleton, 1940. *An Introduction to Corporate Accounting Standards*. Sarasota, FL: American Accounting Association.

Porter, M., 1980. *Competitive Strategy*. New York, NY: Simon and Schuster.

Porter, M., 1985. *Competitive Advantage*. New York, NY: Free Press.

Previts, G. and B. Merino, 1998. *A History of Accountancy in the United States*. Columbus, OH: Ohio State University Press.

Price, G., 1970. Selection and covariance. *Nature* 227 (5257): 520-521.

Price, G., 1972. Extension of covariance selection mathematics. *Annals of Human Genetics* 35 (4): 485-490.

Putnam, G. E., 1921. Joint cost in the packing industry. *Journal of Political Economy* 29 (4): 293-303.

Quartz, S. and T. Sejnowski, 1997. The neural basis for cognitive development: A constructivist manifesto, *Behavioral and Brain Sciences* 20 (4): 537-596.

Richerson, P. and R. Boyd, 2005. *Not by Genes Alone*. University of Chicago Press, Chicago, IL.

Rogers, E., 2003. *Diffusion of Innovations*. New York, NY: Free Press.

Rosenzweig, M. R., E. L. Bennett, and M. C. Diamond, 1972. The brain changes in response to experience, *Scientific American* 226 (2): 22-29.

Rubin, P.A., 1977. Why is the common law efficient? *The Journal of Legal Studies* 6 (1): 51-63.

Russell, B. and A. N. Whitehead, 1910. *Principia Mathematica*, Vol. 1. Cambridge, UK: Cambridge University Press.

Sahlins, M., 1972. *Stone Age Economics*, New York, NY: Aldine De Gruyter

Sangster, A., 2016. The genesis of double entry bookkeeping, *The Accounting Review* 91 (1): 299-315.

Schelling, T. C., 1995. What do economists know? *The American Economist* 39 (1): 20–22.

Schlaug, G., 2001. The brain of musicians: a model for functional and structural adaptation, *Annals of the New York Academy of Sciences* 930: 281-290.

Schmandt-Besserat, D., 1992a, *Before Writing: Vol. I, From Counting to Cuneiform*, Austin, TX: University of Texas Press.

Schmandt-Besserat, D., 1992b, *Before Writing: Vol. II, A Catalogue of Near Eastern Tokens*, Austin, TX: University of Texas Press.

Schumpeter, J., 1950. *Capitalism, Socialism, and Democracy* (3rd ed.). New York: Harper & Row.

Seligman, M., P. Railton, R. Baumeister, and C. Sripada, 2016. *Homo Prospectus*. Oxford, UK: Oxford University Press.

Shatz, C., 1992. The developing brain, *Scientific American* 267 (3): 60-67.

Simon, H., 1962. The architecture of complexity. *Proceedings of the American Philosophical Society* 106 (6): 467-482.

Sivakumar, K. and G. Waymire, 1993. The information content of earnings in a discretionary reporting environment: evidence from NYSE industrials, 1905-10. *Journal of Accounting Research* 31 (1): 62-91.

Skeide, M.A., U. Kumar, R. K. Mishra, V. N. Tripathi, A. Guleria, J. P. Singh, F. Eisner, F. Huettig, 2017. Learning to read alters cortico-subcortical cross-talk in the visual system of illiterates, *Science Advances* 3 (5): e1602612.

Smith, A., 1776/1976. *An Inquiry into the Causes of the Wealth of Nations*. Chicago, IL: University of Chicago Press.

Smith, V., 2003. Constructivist and ecological rationality in economics. *The American Economic Review* 93 (3): 465-508.

Sombart, W., 1902. *Der moderne Kapitalismus.* Leipzig, Germany: Duncker & Humblot.

Sombart, W., 1915. *The Quintessence of Capitalism*. New York, NY: E.F. Dutton & Co.

Sombart, W., 1924. *Der moderne Kapitalismus*, 6th Ed. Leipzig, Germany: Duncker & Humblot.

Steinmetz, G., 2015. *The Richest Man Who Ever Lived*. New York, NY: Simon & Schuster.

Stevin, S., 1607. *Vorstelicke Bouckhouding op de Italiaensche Wyse*. Leiden: Jan Bouwensz.

Suddendorf, T. and M. Corballis, 2007. The evolution of foresight: what is mental time travel, and is it unique to humans? *Behavioral and Brain Sciences* 30: 299-351.

Sunder, S., 2005. Minding our manners: accounting as social norms." *The British Accounting Review* **37**: 367-387.

Sy, A., and A. M. Tinker, 2006. Bury Pacioli in Africa: A bookkeeper's reification of accountancy, *Abacus* 42 (1): 105-127.

Tennie, C., J. Call, and M. Tomasello, 2009. Ratcheting up the ratchet: on the evolution of cumulative culture. *Philosophical Transactions: Biological Sciences* 364 (1528): 2405-2415.

Thompson, W., 1777. *The Accomptant's Oracle*, vol. 2. York: N. Nickson.

Tinbergen, N., 1963. On aims and methods in ethology. *Zeitschrift fur Tierpsychologie* 20: 410-463. Facsimile published in *Ani mal Biology* 55(4): 297-321, 2005.

Tom, S., C. Fox, C. Trespel, and R. Poldrack. 2007. The neural basis of loss aversion in decision-making under risk. *Science* 315 (5811): 515-518.

Tomasello, M., 1999. *The Cultural Origins of Human Cognition*. Cambridge, MA: Harvard University Press.

Vatter, W., 1950. *Managerial Accounting*. New York, NY: Prentice Hall.

Walton, S. (with J. Huey), 1992. *Made in America: My Story*. New York, NY: Bantam Books.

Waymire, G., 2009. Exchange guidance is the fundamental demand for accounting, *The Accounting Review* 84 (1): 53-62.

Waymire, G. and S. Basu, 2007. Accounting is an evolved institution. *Foundations and Trends in Accounting* 2 (1-2): 1-174.

Waymire, G. and S. Basu, 2011. Economic crisis and accounting evolution, *Accounting and Business Research* 41 (3): 207-232.

Wilson, E. O., 2017. *The Origins of Crreativity*. New York, NY: Liveright Publishing

Wilson, E. O., 2019. *Genesis: The Deep Origins of Society*. New York, NY: Liveright Publishing.

Winjum, J. O., 1970. Accounting in its age of stagnation, *The Accounting Review* 45 (4): 743-761.

Winjum, J. O., 1971. Accounting and the rise of capitalism: an accountant's view, *Journal of Accounting Research* 9 (2): 333-350.

Winjum, J. O., 1972. *The Role of Accounting in the Economic Development of England: 1500-1750*. Champaign, IL: Center for International Education and Research in Accounting (University of Illinois).

Yamey, B. S., 1949. Scientific bookkeeping and the rise of capitalism, *The Economic History Review* 1 (2/3): 99-113.

Yamey, B. S., 1964. Accounting and the rise of capitalism, *Journal of Accounting Research* 2 (2): 117-136.

Yamey, B. S., 2000. The 'particular gain or loss on each item we deal in': an aspect of mercantile accounting, 1300-1800, *Accounting, Business and Financial History* 10 (1): 1-12.

Yamey, B. S., 2005. The historical significance of double-entry bookkeeping: some non-Sombartian claims. *Accounting, Business and Financial History* 15 (1): 77-88.

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.

Zeff, S., 1972. *Forging Accounting Principles in Five Countries: A History and Analysis of Trends*. Champaign, IL: Stipes Publishing Co.

Zeff, S., 1986. Big Eight firms and the accounting literature: the falloff in advocacy writing. *Journal of Accounting, Auditing and Finance* 1 (2): 131-154.

Zerbi, T., 1952. *La Origini della partita doppia: Gestioni aziendali e situazioni di mercato nei secoli XIV e XV.* Milan, Italy: Marzorati.

**Figure 1**
**Co-Evolution of Accounting, Exchange, & Exchange Evaluation with DEB vs. SEB**

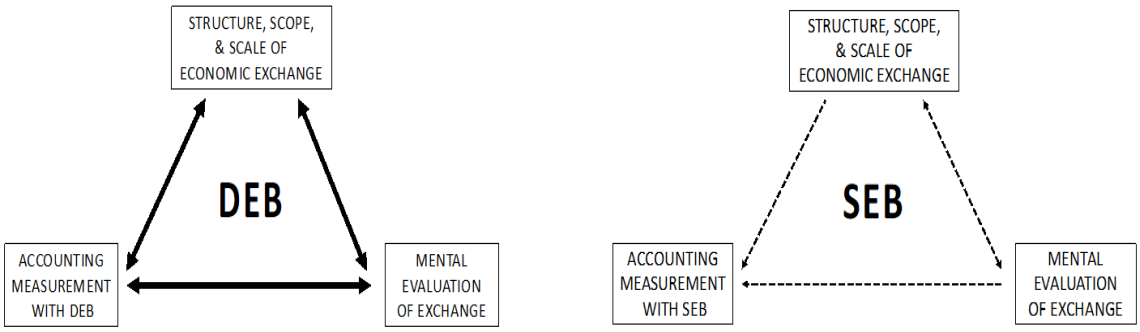
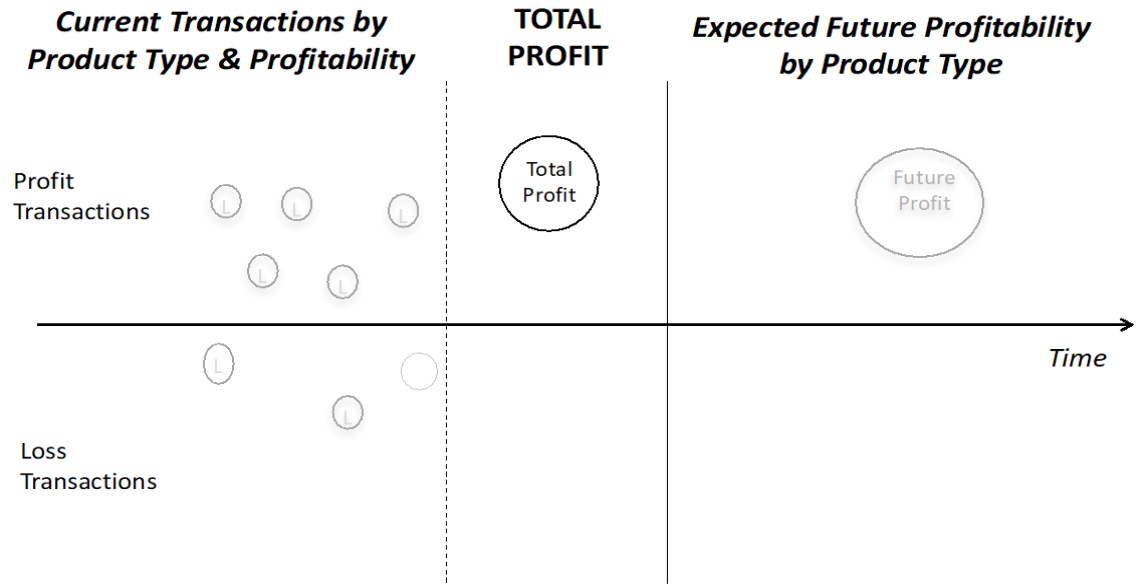


**Figure 2**
**Clarity of Past & Future Transactions with SEB vs. DEB Accounting for a Two-Product Firm**

**A: DEB**




**B: DEB**

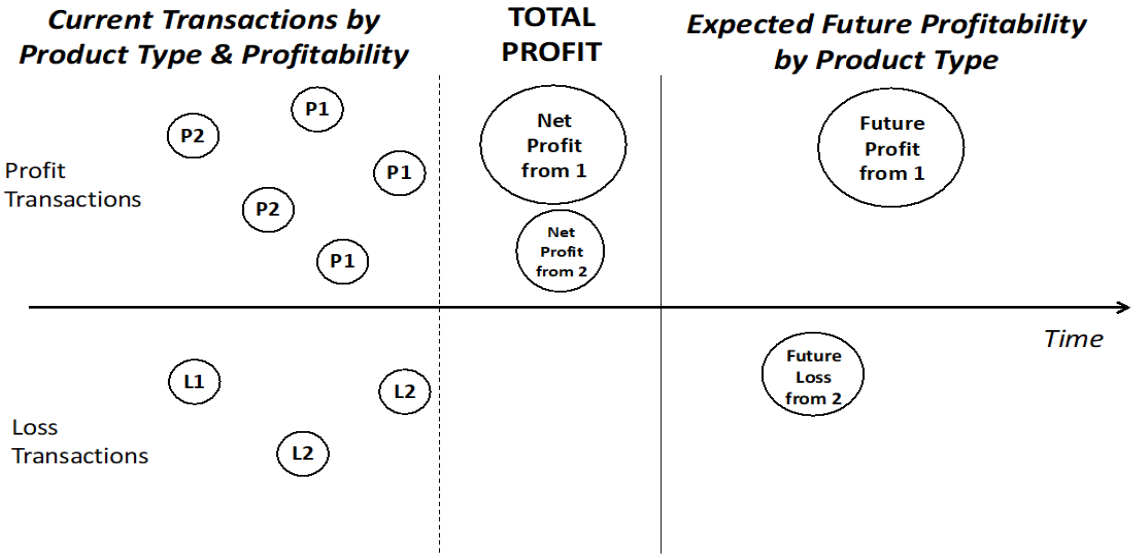
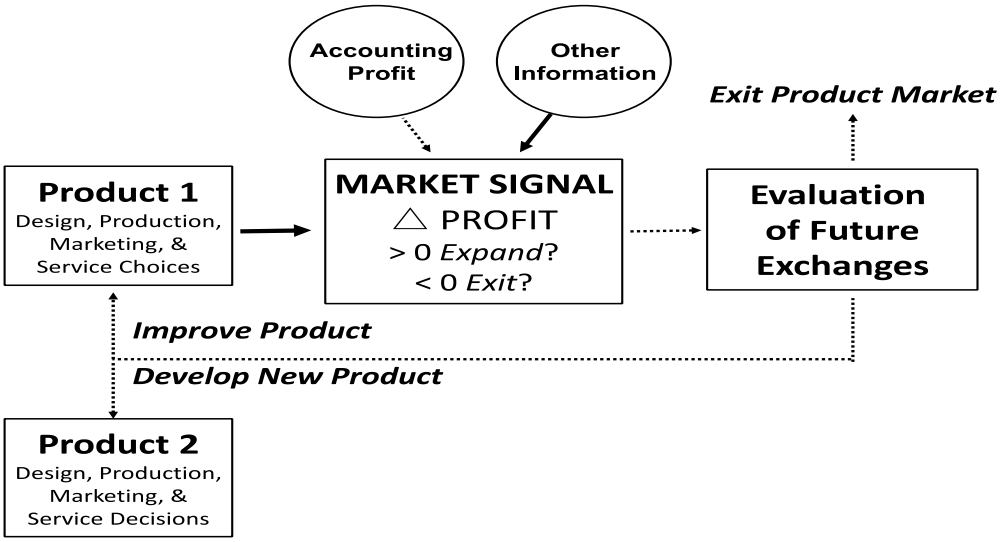


**Figure 3**
**Feedback Loop from Accounting Profit in Exchange Evaluation Under SEB and DEB**

**A: SEB-BASED EVALUATION (Weaker Feedback)**




**B: DEB-BASED EVALUATION (Stronger Feedback)**